

FUNCTIONAL FOODS AND NUTRACEUTICALS SERIES

Food as Medicine

Functional Food Plants of Africa

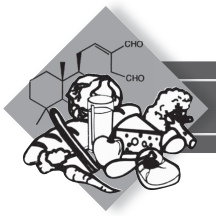


Maurice M. Iwu

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Functional Food Plants of Africa



FUNCTIONAL FOODS AND NUTRACEUTICALS SERIES

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Maurice M. Iwu

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Series Preface

The shift from their traditional African diet to a more Western model has harmed the health status of the African populace by increasing the prevalence of noncommunicable diseases, but as an after effect, it brought about a resurgence of interest in the composition and functionality of the traditional African diet. Currently, a wide range of indigenous plant-derived health and nutritional products are utilized across the length and breadth of the African continent, and these products have been instrumental in improving human health problems. Africa has made a great contribution to the world agriculture via plant-based food products that crossed the Atlantic to the Americas during past centuries. This book, *Food as Medicine: Functional Food Plants of Africa*, focuses on some key plants to provide a comprehensive overview of recent scientific, technical, and economic developments across a broad range of nutritional, medicinal and aromatic plants, and plant-based food products. The features of processing, from indigenous African technologies through to the modern era, in addition to sustainability-sustained-yield, cultivation, and the combined use of medicinal and spice plants in foods and beverages are showing great potential in the future developments of agriculture and functional food products.

Information regarding plant-based functional foods in the African diets as well as the role of nonnutritive phytochemicals in enhancing health and well-being and the prevention of noncommunicable diseases are serious issues facing the world. This book will be of interest to researchers, academics, students, and industry personnel who are engaged in nutraceutical, natural product, and herbal research in universities, research institutions, and relevant industries around the world. Given the growing interest in natural products, nutraceuticals, and the potential health benefits of plant-based functional foods, this book is a timely addition to the "Functional Foods and Nutraceuticals Series."

John Shi, PhD, Series Editor
Senior Research Scientist
Guelph Research and Development Center
Federal Department of Agriculture and Agri-Food Canada
Ontario, Canada



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Preface

Africa as the cradle of human civilization has the longest history of the domestication of plants for food and medicine. The utilization of the enormous biodiversity of the continent is multidimensional and has yielded many foods, medicines, tools, and objects for games and recreation. This book focuses on botanicals that serve as constituents of both the local diet and an herbal pharmacopeia. Evidence for the use of African dietary plants for health maintenance is backed by a large body of information accumulated over several decades. It is suggested that an examination of these plants within a therapeutic context facilitates a more comprehensive understanding of the role that these plants play in the diet. The appearance of these biologically active species as dietary constituents is subsequently discussed with reference to their potential effect on the occurrence and expression of many diseases. Conversely, recognition of the potential role of these herbs and their physiologically active constituents in health optimization, not only for disease prevention and treatment, will support their continued use and the appreciation of their role in nutrition. Although the focus is on African cultures and their flora as functional foods, the data discussed in the book and the analyses therein have wider implications for global nutrition and health.

The approach is to present a list of carefully selected food plants that have well-documented medicinal applications as scientific probes to analyze the potential health impact of such African dietary plants within the context of micronutrient sufficiency, health improvement, and the overall economic well-being of the continent. The conceptual framework calls attention first to the study and sustainable utilization of these food plants, second to the adoption of some of them as economic crops for wider cultivation, which in nearly every case will also improve the quality of lives of rural African communities, and third to the initiation of discourse on the functionality and production of African foods with health benefits. The high rate of urbanization in Africa with large populations abandoning their communities to live in multicultural settings invariably leads to rapid nutrition transitions, which cause increased rates of chronic diseases (e.g., diabetes, obesity, cancer, heart disease, osteoporosis, and various degenerative diseases) as people shift from traditional diets (with the protective functional foods from the forests) to more calorie-rich diets derived from adopting the food systems of more developed nations. It is interesting to observe that urban dwellers and wealthy Africans with their consumption of cheap processed foods (or so-called fast foods) from developed countries exhibit disease patterns that parallel those of the urban poor in the West, while the health status of the nutrition-cautious elites in developed nations approximates those of African rural dwellers.

This book provides an impetus for making a closer connection between agriculture and health and addresses gaps in our understanding of the elements and interactive systems at the intersection of agriculture and food, food and people, and people and health. It follows that a better understanding of African functional foods will provide a platform to produce micronutrient-rich plant varieties that address deficiencies in the availability of essential nutrients. Vitamin A deficiency, for example, can be dealt with by encouraging the consumption of red palm oil (from the fruits of the palm tree *Elaeis guineensis*), tomatoes, and a variety of yellow, orange, and red vegetables and fruits, as well as by introducing β-carotene-rich crops into the rural agriculture system. Crops known to be rich in β-carotene include selected varieties of pulses such as pigeon pea, cowpea, chickpea,

cereals like maize and sorghum, and root crops like cassava and orange-fleshed sweet potato.

The emphasis throughout the book remains on African food plants that contain substances that confer physiological functionality to them rather than the constituents themselves. In this respect, the chemical constituents are used mainly as characteristics of the identity of the plant species rather than as the basis or the explanation of their use as dietary supplements or functional food. They are food—with observed functionality. This approach presupposes that isolated ingredients and chemically defined entities from African food plants used in the prevention and treatment of diseases are not necessarily functional food and therefore not included. Such ingredients, however, can be used in the fortification of natural functional foods. They are classified in this book as "nutraceuticals." Several studies have shown that the two categories—whole plants and isolated ingredients from such food plants—may exhibit different profiles. A normative example is green tea (*Camellia sinensis*), whose health benefits have been well documented, including in the management of depression, detoxification, cancer prevention, anti-inflammation, and amelioration of aging complications. The most important of green tea constituents are the catechins, in which (–)-epigallocatechin-3-*O*-gallate is predominant. Whereas their beneficial effects have been studied extensively, a small number of adverse events have been reported in the medical literature. Hepatotoxicity has been observed severally by the consumption of purified and concentrated extracts as pharmaceutical preparations in high doses but such liver toxicity does not occur significantly in green tea taken as brewed teas. The health-promoting effects of β-carotene found in carrots, palm oil, tomatoes, and several vegetables and fruits are well known and confirmed by many epidemiological studies. Ingestion of large amounts of β-carotene or foods rich with the compound has not been associated with any serious side effects. In laboratory studies on rats, rabbits, and dogs, embryotoxicity was not observed in multiple generations of the animals given up to 1 g/kg/day of β-carotene for several months. However, the compound has been found to have the capacity to decrease the serum concentration of vitamin E over a long time (>9 months). Evidence suggests that both antioxidants promote DNA adduct formation indirectly by inhibition of the protective enzyme glutathione-*S*-transferase π. Despite their opposite image, both antioxidants display a similar type of toxicity. Although β-carotene and its related naturally occurring analogs have shown exceptional ability to prevent cancers, including lung cancer, some negative correlation has been observed in a few studies between plasma levels of β-carotene and lung cancer morbidity, especially among smokers. These findings suggest that dietary supplements such as β-carotene should not be considered as therapeutic agents since their functionality manifests better as components of the human diet.

African functional foods, therefore, should not be viewed as herbal medicines to be subjected to the same proof of efficacy, such as double-blind clinical trials, used in the evaluation of drugs. They are sometimes used as ingredients in the preparation of traditional medicines but they should not be considered as therapeutic agents. All plants used as functional foods may be regarded as medicinal plants; however, not all medicinal plants are functional foods. In some cases, like most foods, the method of processing and preparation determines their proper use as functional foods, traditional medicine drugs, or phytomedicines. The West African bitter leaf (*Vernonia amygdalina*), for example, is used as a vegetable in soups for which it is soaked and washed several times in water to remove several alkaloids and sesquiterpenes before adding. For the management of diabetes, the whole leaf is taken dry as teas or the expressed juice is taken as a medicine. The standardized extract is used as a phytomedicine for the prevention of cancer and other diseases.

The multiple use of the poisonous castor bean further underscores the point. Castor oil, a well-known constituent of the castor bean (*Ricinus communis* L.), is used as a purgative and as an emollient. The oil, which has several industrial applications, also contains a very poisonous heat-labile lectin called ricin. Ricin can be fatal if it is inhaled, ingested, or injected, with a median lethal dose (LD_{50}) of 22 μg/kg body weight. In addition to its industrial applications, the by-product, castor cake, is also used as manure. The leaves when fresh can be used to feed the *eri* silkworm, and the dry leaves are used as an insecticide. The same seed that produces a very poisonous compound yields, after fermentation, a popular food condiment called *ogiri*, which is used among the tribes of Eastern and Central Nigeria (especially the Igbo) as a taste enhancer in many dishes. Further, castor plays a very important role in the economy of the arid and semiarid regions of the continent as it has the ability to grow under dryland conditions.

Another important reason for doing this review is to improve the sustainable sourcing and conservation of these African food plants and thereby enhance their availability in commerce. The number of food ingredients used in Africa is becoming increasingly narrow due to rapid urbanization; therefore, the provision of information on neglected but functional food plants may improve the health of the continent and encourage their cultivation. Although there is renewed interest in the use of African medicinal plants, including functional foods, most of the plants are wild-crafted, which poses immense pressure on the conservation of such species. The demand that will be generated by creating this type of enlightenment and awareness will make it feasible to use modern biotechnological techniques to sustain these valuable botanical entities, especially to meet the anticipated increase in demand by the pharmaceutical and food industries.

Currently, African medicinal and food plants are not major articles of trade in the global market. Only about 10% of over 5000 plant species used in traditional medicine in Africa have been commercialized in any significant manner, with less than 100 medicinal species traded on the international market. A recent review by Dr. Ben-Erik Van Wyk (see Chapter 1 for details and references) showed that only four African medicinal plants were included in the four volumes of the *Selected Monographs of Medicinal Plants* published by the World Health Organization (WHO, 1999, 2003, 2007, 2009). These are *Aloe ferox* (vol. 1, p. 33), *Commiphora myrrha* (as *C. molmol*) (vol. 3, p. 247), *Harpagophytum procumbens* (vol. 3, p. 182), and *Prunus africana* (vol. 2, p. 246). When plants that occur in Africa and other regions of the world are included, the number of species can be adjusted to 12 out of the 118 species reviewed in the monographs. These figures indicate that enormous potential exists for the development of African indigenous functional foods as commercial products for the domestic and international markets.

Evidence abounds to show that most of the products sold in Europe and America that purport to contain African herbal products are indeed made with ingredients of questionable identity and origin. The popular *ogbono* seeds, African bush mango (*Irvingia gabonensis*), used as a condiment for the preparation of the West African "draw soup" is a highly prized weight-loss medicine in Europe and America. However, a random survey by the U.S. Department of Agriculture of 17 proprietary products from American dietary supplements shops showed that none of the products that claimed to contain African bush mango contained any *Irvingia*. In September 2015, the Attorney General of the State of New York, Eric Schneidermans, ordered 13 dietary supplement makers and distributors to halt the sale of "adulterated" products that claim to be derived from the devil's claw plant, *Harpagophytum procumbens*, marketed as a treatment for arthritis and other forms of joint pain. It was stated that a study by the New York Botanical Garden, however, concluded that supplements made or distributed by the companies contained a cheaper related

species, *Harpagophytum zeyheri*. Both species are native to the Kalahari Desert of Southern Africa. *H. zeyheri* contains some but not all of the chemicals found in devil's claw and the two plants are used interchangeably in commerce but not among the natives of the land of origin, in which it is found. In February of the same year, the Attorney General directed four major retailers to stop the sale of some herbal supplements after DNA tests failed to detect the plant materials listed on most products tested. These cases of adulterations can be attributed partly to the scarcity of the authentic plant species from Africa.

In the chapters that follow, I have presented an outline of major dietary plants that are used both for food and for medicine. The herbs and dietary supplements listed were selected based on their usefulness in the promotion of good health and not the treatment of diseases. Most of the information outlined in the book are based on literature-related discovery, which is the linking of two or more scientific literature concepts that have heretofore not been linked (i.e., disjoint), in order to produce novel, interesting, plausible, and intelligible knowledge (i.e., potential discovery). Some of the data are based on primary information obtained from over 25 years of field work and practice, and personal communication and reports from other investigators. It is neither a book on nutrition nor a book on phytochemistry but as the title indicates, a review of *Food as Medicine: Functional Food Plants of Africa*.

The conceptual framework for this book was originally developed by Dr. Nigel Gericke of South Africa, who also suggested that I lead the discussion on this important subject. I thank him immensely for the opportunity and for the many successful projects he has initiated in Africa since our chance meeting in Maryland, USA several years ago. I remain grateful to my wife Kate and members of my family for their support and encouragement to write this book. My gratitude also goes to my colleagues and associates, Professor Elijah Sokomba, Mrs Ijeoma Nwafor, Paschal Okwara, Pharm. Iduh, Mildred Udeagbala, Ugochi Uwandu, Chinyere Douglas, and the staff of Bioresources Development Group for their considerable assistance that made this book possible.

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Maurice M. Iwu, PhD
Abuja, Nigeria

Author

Professor Maurice M. Iwu earned Master of Pharmacy and PhD in pharmacognosy in 1978 from the University of Bradford, Bradford, England. He was awarded the Doctor of Letters degree (Honoraris Causa) by Imo State University, Nigeria in 2009. He was a professor of pharmacognosy at the University of Nigeria, Nsukka and a senior research associate at the Division of Experimental Therapeutics of Walter Reed Army Institute of Research, Washington, DC. He is the president of Bioresources Development Group (BDG), an African-based independent biosciences research and development organization that cultivates, processes, and produces medicines and cosmetics from natural products. He is also a member of the Board of Directors of Neimeth International Pharmaceuticals Plc. He is the founder and chairman of Bioresources Development and Conservation Programme (BDCP) in Nigeria and Cameroon, Bioresources Institute of Nigeria (BION) and the International Centre for Ethnomedicine and Drug Development (InterCEDD), he was the vice president, Research and Development at Tom's of Maine (a personal care manufacturing company in Maine, USA). He is the chairman of the Board of Directors of InterCEDD Health Products, a dietary supplements manufacturing and marketing company, and Nature's Emporium a chain of health and wellness outlets in major cities in Nigeria.

He attended the *Leadership and Strategy in Pharmaceuticals and Biotech* Course (Course 10) at the Harvard Business School, Boston (USA). Professor Iwu has received many academic and professional honors among which are the World Health Organization (WHO) Visiting Scholar to the Dyson Perrins Laboratory, University of Oxford (1980); Fulbright Senior Scholar Award–Ohio State University, Columbus Ohio, and the Department of Chemistry, Columbia University, New York (1983); Senior Research Scholar Award, U.S. National Research Council, Washington, DC (1993–1995); and the Richard Schultz International Prize for Ethnobiology (1999). Dr. Iwu also received a commendation and tribute from the United States House of Representatives, 106th Congress of the United States of America (February 16, 2002). Professor Iwu has presented over 300 scientific papers, published more than 200 research articles, and is the author of 4 books, including the highly cited *Handbook of African Medicinal Plants* (first edition 1994; second edition 2014) published by CRC Press, Boca Raton, Florida. He is the series editor of the Elsevier Science Series *Advances in Phytomedicine*. He is also a member of the editorial boards of several international scientific journals. He has a number of patents to his credit.

Professor Iwu currently serves as a member of the Treatment Research Group (TRG) on Ebola virus disease established by the Nigeria's Federal Ministry of Health and as a member of the Clinical Trial Technical Working Group (CT-TWG) of the National Agency for Food and Drug Administration and Control (NAFDAC) of Nigeria. Professor Iwu and his wife Kate have children and grandchildren.



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Section I

Introduction to African Functional Foods



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1

Foods, Phytochemicals, and Nutraceuticals: The New Health Imperative

Let thy food be thy medicine and thy medicine be thy food.

Hippocrates
Father of modern medicine

A healthy diet is essential for the sustenance of human life. In the past, food was regarded simply as a source of energy at a time when strenuous manual labor involving high energy consumption was the norm. In many parts of the world, this concept of food did not change until after the Second World War when people became engaged in more sedentary occupations and lifestyles. In this modern era, food has assumed a whole new meaning and has increasingly become a cultural and social phenomenon rather than a basic activity to ensure survival. It is no longer sufficient for a healthy diet to provide only the major nutrients at adequate levels; a healthy diet should also be able to optimize health and help the body to fight diseases. In other words, besides supplying nutrients at adequate quantities and quality, a healthy diet should have additional functional attributes. Such protection is achieved by the presence of bioactive compounds contained in certain foods, which we now refer to as "functional foods." This intrinsic relationship between diet and health has been known for over 2000 years, even in the days of the famous Greek physician, Hippocrates (400 BC), who wrote the advice quoted at the beginning of this chapter. Other ancient scholars also recognized the link between diet and good health as evidenced by early medical treatises written by Cicero (about 44 BC), Galen (about 180 AD), and Avicenna (about 1000 AD), but the first medical insight into the link among longevity, quality of life, and diet was attributed to Alvise Cornaro in his "Discourses on the Sober Life" about 1560. The utility of his work was, however, limited by the fact that his suggestions were based on personal experiences rather than on objective observations. It is interesting to note that his recommendations at that time are similar to the recent theory of caloric restriction but the link is likely a casual one.[1]

> Nutrition is a key element to any strategy to reduce the global burden of disease. Hunger, malnutrition, obesity and unsafe food all cause disease, and better nutrition will translate into large improvements in health among all of us, irrespective of our wealth and home country.
>
> **Dr. Bro Harlem Brundtland**
> *Director General, World Health Organization, United Nations, World Economic Forum (2002)*

There has been a rapid increase in the global incidence of cancers, obesity, and various endemic chronic diseases from attention deficit hyperactivity disorder (ADHD), Alzheimer's disease, and autism to osteoarthritis and stroke. Heart failure and metabolic

diseases are now the leading causes of death in some countries. For several decades, the epidemic, regarded as mainly a problem of the Western world, was blamed on its modern agricultural techniques, mass production, and easy access to and large consumption of agricultural foods, including those frequently industrially manipulated and processed such as meat, dairy, and wheat.[2] However, similar development is also now observed in other parts of the world, largely in parallel to the adoption of a "modern"/Western lifestyle. African city dwellers who embrace the same lifestyles as their Western counterparts are in fact not only suffering from the same diseases as the people in the West but at far greater rate and intensity. This epidemic of obesity and associated diseases that has its epicenter in Southern United States, with states like Alabama, Louisiana, and Mississippi having the highest incidence of obesity and chronic diseases in the United States and the world, is now ravaging many parts of Africa, especially among the rich who no longer consume the bioprotective African ethnic foods in preference to a proinflammatory cuisine.

It is only within the last 20 years that carefully controlled studies and metadata analysis have revealed that healthy eating and physical exercise have direct impact not only in the prevention of illness but also in the reversal of certain diseases, especially the drastic amelioration of most metabolic syndromes and age-related macular degeneration. The use of soups and special meals to treat certain diseases is almost a universal concept, with the recipes of healthy living varying among cultures. Diets rich in vegetables, fruits, and whole grain have been shown by several studies to be good for our heath, whereas diets composed mainly of fast foods, sugar, meat, butter, and overprocessed or refined food are known to be injurious to health. The boundary between food and medicine is becoming increasing blurred. Experts are beginning to redefine what constitutes food (*materia dietetica*, food substances) and what constitutes medicine (*materia medica*, medicinal substances) in order to differentiate the satiation role of food substances from the functionality of components of food that promotes optimal health. It is generally accepted that the mechanism of how the food–medicine interface translates into people's lifestyles is far more complex than hitherto understood.

The saying that "we are what we eat" resonates in the health status of people who consume fruits, vegetables, and wholesome foods as opposed to people who eat overprocessed food. What we eat can also affect our minds, even our behavior, and our general disposition toward others. It has been established that too much refined, rich, sugary food can lead to heart diseases and certain types of cancer. It is also a scientific fact that binging on meat, butter, and cheese is bad for our health; not eating enough fruits and vegetables may lower our resistance to diseases; obesity is a disease that makes us even more disposed to other illnesses; and fatness is the foe of fitness. Yet these facts have been obscured because of the millions spent by the food industry in advertisements and fraudulent research that promote unhealthy diets in order to maximize profit.

Increasingly, foods are not consumed or intended only to satisfy hunger and to provide necessary nutrients for humans but also to prevent certain diseases and to improve the physical and mental well-being of consumers. Healthy eating includes the consumption of foods that go beyond the basics of supplying nutrients to the body but that also include substances that appear to help ward off and combat certain chronic illnesses. Such foods with specific health-enhancing benefits are called "functional foods." There is no general agreement on the definition of the term "functional food" but a widely used definition is that of a food substance that possesses an additional physiological function beyond its nutritional value (often one related to health promotion or disease prevention) or by adding new ingredients or more of existing ingredients to confer additional health benefits

to a food substance. For the purposes of this book, however, the functionality is due to naturally occurring constituents of the food plant and not food with added substances to enhance its physiological activity. At the 9th International Conference on "Functional Foods and Chronic Diseases: Science and Practice" held at the University of Nevada, Las Vegas on March 15–17, 2011, a definition was proposed:

> Functional Food is a Natural or processed food that contains known biologically-active compounds which when in defined quantitative and qualitative amounts provides a clinically proven and documented health benefit, and thus, an important source in the prevention, management and treatment of chronic diseases of the modern age.

Perhaps, the conceptual framework for the advent of functional foods can be traced back to the pioneering work of the Hungarian biochemist Albert Szent-Gyorgyi de Nagyrápolt (1893–1986), who in 1940 postulated that certain secondary plant metabolite, a so-called vitamin P, is capable of improving the health status of individuals who consume it. The plant metabolite so described by the winner of the 1937 Nobel Prize in Medicine was never established as a "vitamin" because no disease was ever traceable to a deficiency of this "vitamin P." Szent-Györgyi, however, is immortalized by his work on the discovery of vitamin C and the components and reactions of the citric acid cycle, cellular respiration, the identification of fumaric acid, and other steps in what would become known as the Krebs cycle. Flavonoids and related polyphenols were considered possible components of the nonessential but beneficial nutrient that was called vitamin P. It was not until the 1970s that a class of secondary plant metabolites, mainly polyphenols, were considered nonnutritional compounds with beneficial health effects. By the 1990s, the potential role of antioxidants as modulators of various diseases, especially noncommunicable diseases, was fully recognized. Subsequently, other classes of compounds that occur normally in food were identified, verified, and adopted as an essential component of a healthy lifestyle. In a fundamental sense, functional foods as a concept is based on the idea of a vitamin P as suggested by Szent-Györgyi.

The concept of functional food, however, was first introduced in the 1980s by Japanese scientists who studied the relationships among nutrition, sensory satisfaction, fortification, and modulation of physiological systems. Foods considered as functional foods are so recognized in Japan, many Asian countries, and Eastern Europe as a specific food category and are so labeled. In 1991, the Ministry of Health (Japan) introduced rules for approval of a specific health-related food category called FOSHU (FOod for Specified Health Uses), which included the establishment of specific health claims for this type of food. In Western Europe and the Americas, functional foods are regarded as more of a concept than a definite category of food. The generally accepted definition of functional food is as stated above to denote a food substances that have a functional effect beyond its known nutritional value.

Requirements for FOSHU Approval (Japan Ministry of Health, Labour, and Welfare):

- Effectiveness on the human body is clearly proven.
- Absence of any safety issues (animal toxicity tests, confirmation of effects in the cases of excess intake, etc.).
- Use of nutritionally appropriate ingredients (e.g., no excessive use of salt).
- Guarantee of compatibility with product specifications by the time of consumption.
- Established quality control methods, such as specifications of products and ingredients, processes, and methods of analysis.

In traditional African societies, food is clearly used both for satiation and for health-promoting properties. Specific vegetables are prescribed for common colds and catarrh, abdominal pains, infections, to enhance female fertility, to promote male sexual virility, and various chronic conditions. Certain spices, resins, and bitter plant products with some physiological activities are deliberately added to many traditional recipes to enhance their health-promoting properties. Some have argued that the increase in the incidence of many metabolic diseases, cancers, and chronic diseases could be due, at least in part, to the abandonment of these protective traditional remedies for processed imported food by the African elite. The ethnobotanical studies of several African tribes have revealed the multidimensional aspects of plant use in which botanicals serve as constituents of both the local diet and an herbal pharmacopeia.[3,4]

> Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.
>
> **WHO**[5]

In today's health-conscious populations, where people are worried about lifestyle-induced health risks and the consequences of modernization, such as the effect of pesticide residue, genetic modification, concerns about cell phones, high-tension power lines, vaccination programs, hormones and additives in food, and the chronic exposure to cancer-inducing radiation, there is an ever-increasing demand for functional foods that could protect individuals from such adverse agents.

Some of the contemporary questions include

What is the right food for optimum health or to treat a specific disease?

Which food is better eaten raw and which is better cooked or fermented?

When is food taken merely for satiation and general nutrition?

How dangerous are processed food to our health?

Is it possible to be relatively disease-free by adhering to natural foods?

There are indeed no simple answers to these fundamental questions. Yet people from every culture, race, and continent are interested in knowing what are the best types of food and which food substances are not only healthy but can be useful in the prevention and treatment of certain diseases when consumed in an appropriate manner.

Life expectancy has risen significantly in most parts of the world. It is no longer news to learn of people living productively way beyond 80 years of age and some individuals living well beyond 100 years in some countries. The need of the aging population for healthy food and dietary supplements has also risen exponentially. Health foods have become essential to cater for the new generation of youngish-aged who require a different kind of nutrition.

Food generally consists of three main ingredients: proteins, carbohydrates, and fats. Plants used as food produce varying quantities of these macronutrients and at different ratios. Apart from these major food components, plants also contain other trace compounds that help the body to maintain essential body functions. Some of these critical compounds found also in some nonplant diets include vitamins and minerals. Continuous and adequate nutrient supplies form the basis of all life on earth. Life therefore cannot exist without the continuous supply of adequate amounts of all essential nutrients. Interestingly, these nutrients work in a collaborative manner as a dynamic system to sustain life. Sometimes

the absorption of one component is dependent on the availability of another. Each is critical in that if even one nutrient is unavailable or insufficient from the nutrient medium or diet of an organism, the organism will ultimately die. The lack of sufficient nutrients to thrive is indeed responsible for millions of deaths each year, both in industrialized and developing countries. The magnitude of this preventable crisis remains embarrassingly high with an estimate by the World Health Organization that over 50% of all deaths on earth are associated with malnutrition.

There are at least 51 known nutrients that human beings require in consistently adequate amounts to live healthy and productive lives. Unfortunately, global food systems, especially in developing countries (which includes all of Africa), are failing to provide adequate quantities of all of these essential nutrients to vast numbers of people. The list includes oxygen, water, and carbohydrates; amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine); fatty acids (linoleic acid and linolenic acid); macrominerals (Na, K, Ca, Mg, S, P, and Cl); trace elements (Fe, Zn, Cu, Mn, I, F, Se, Si, V, As, Li, and Sn); and vitamins (A, D, E, K, C [ascorbic acid], B1 (thiamine), B2 (riboflavin), B3 (niacin), B5 (pantothenic acid), B6 (pyroxidine), B7/H (biotin), B9 (folic acid and folacin), and B12 (cobalamin). Apart from these essential nutrients, there are countless other nutrients that are beneficial for maintenance of optimum health but they lack clearly defined physiological action and their absence in the diet is never life threatening. The incidence of undernutrition is not limited to poor countries alone. Data from the U.S. Centers for Disease Control and Prevention show that thousands of Americans are not getting enough nutrients through food alone, Dr. Tieraona Low Dog told congressional staffers during a briefing on September 9, 2015.[6] According to Dr. Low Dog, millions of Americans do not get enough essential nutrients to ensure their bodies function optimally. The data showed that nearly 90 million Americans have a vitamin D deficiency; 30 million are deficient in vitamin B6; 18 million are deficient in vitamin B12; and nearly 16 million have a vitamin C deficiency.

When the body has insufficient quantities of these trace but useful food components or is unable to convert them from their natural forms to more useable form, several diseases occur. Plants, in addition to being rich in vitamins and minerals, contain these bioactive compounds that literally act as medicines largely at cellular levels to repair damaged tissues, restore normal physiological functions, and enable the body to fight diseases. Some of the compounds found in plants are not necessarily produced by them but are assimilated into their organs as constituents, which makes it possible for the same plant species grown under two different environments to contain a different mix of biochemicals.

1.1 Phytonutrients: Nature's Own Medicine

Plants contain nonnutritive plant chemicals called "phytochemicals," which have protective or disease-preventive properties and a beneficial catalytic role in human metabolism, catabolism and anabolism. The name "phytochemical" is derived from the Greek word "phyto" which means plant and "chemical" to denote chemicals found in plants, including herbs, vegetables, fruits, grains, nuts, and other plant food substances. They dynamically regulate the metabolic functions of proteins, enzymes, transporters, receptors, and signal transduction proteins linked to various lifestyle-related diseases. Epidemiological studies have established that a diet high in vegetables and fruits is associated with a reduced risk for the development of certain diseases, such as cancer, chronic metabolic diseases, and

cardiovascular diseases. Compounds associated with the health-promoting effects of vegetables include glucosinolates and other organosulfur compounds and their degradation products, phytosterols, vitamins, polyphenols, carotenoids, glycolipids, polyacetylenes, and dietary fibers. It has been established by science that these chemicals are produced by plants as growth regulators and to protect themselves against pests, but recent research demonstrates that they can also protect humans against diseases, especially oxidative-stress-related ailments. Unlike vitamins, most phytochemicals are considered as nonessential nutrients because they are not required by the human body for sustaining life. They are useful in optimizing health and preventing certain diseases. Most phytochemicals are sensitive to heat and are often destroyed during cooking and food processing. There are thousands of such phytochemicals occurring in food plants.* Some of the well-known phytochemicals are lycopene in tomatoes, isoflavones in soy, flavonoids in fruits, carotenoids in carrot and red palm oil, diterpenes and sesquiterpenes in spices, alkaloids and phytosterols in vegetables, and even the ubiquitous chlorophyll in all green plants. In functional foods, these phytochemicals are available in a form that enables their physiological activities to be manifest. Major classes and examples are listed in Table 1.1.

1.2 How Do Phytochemicals Work?

Phytochemicals generally provide nonspecific support for recuperation and repair. Their explicit role in phytotherapeutic strategies includes the prevention of certain diseases and the treatment of chronic ailments. Most phytochemicals can be extracted with suitable solvents such as water, alcohol, and petroleum spirit. They can also be isolated as pure compounds and their chemical structures can be determined by chemists. Several thousands of such compounds have been identified and characterized from many plant genera as their major constituents. In large doses, some of them are used as phyto-pharmaceuticals and differ from other drugs only in terms of their origin as plant-derived. Drugs of plant origin or those based on modification of plant-derived molecules include aspirin (willow's bark), digoxin (fox glove), reserpine (*Rauvolfia*), quinine/quinidine, and vincristine (African periwinkle). Some of them, such as strychnine, albrin, and strophantidine, are quite toxic and should be handled with care.

Our interest, however, is mainly in another type of phytochemicals that occur in small quantities and are found in edible plants. There are many such phytochemicals found in foods, with different positive health outcomes associated with them. They are sometimes erroneously considered as pharmacologically inert substances because they are virtually devoid of harmful side effects even at extremely large doses. It is unlikely that substances that belong to this category will exert significant pharmacological activity when subjected to the same pharmacological tests used to validate drugs. Even the reports of positive clinical observation and epidemiological-based evidence that are often used to validate such substances may not readily fit into the double-blind controlled clinical trials that have become widely accepted as the gold standard of evidence-based medicine. Many experts have wondered how substances that "do nothing" could be of any use by "doing nothing."[7]

* There are around 9000 types of phenolics, including flavonoids, anthraquinones, and phenylpropanoids; about 30,000 terpenoids, including terpenes, carotenoids, xanthophylls, and iridoids; 15,000 alkaloids; and several sulfate-containing chemicals such as isothiocyanates.

TABLE 1.1

Examples of Bioactive Phytochemicals Isolated from Medicinal Plants

Chemical Classes	Compounds
Alkaloids	Nicotine, nornicotine, anabasine, anatabine, vincristine, vinblastine, symphytine, 7-acetyllycopsamine, 7-acetylintermedine, piperine, coniine, trigonelline, pilocarpine, cytisine, sparteine, pelletierine, hygrine, atropine, ecgonine, scopolamine, catuabine, quinine, strychnine, brucine, morphine, codeine, thebaine, papaverine, narcotine, sanguinarine, narceine, hydrastine, berberine, emetine, ephedrine, serotonin, ergine, caffeine, theobromine, capsaicin
Amines	Pyrrolidine (tetrahydropyrrole), piperidine, piperazine
Cyanogenic glycosides	Laetrile (amygdalin), prunasin, sambunigrin, taxiphyllin, dhurrin, linamarin, lotaustralin, vicianin
Diterpenes	Retinoids, retinol, taxol, dihydrogrindelic acid, labd-13*E*-en-15-oate, dihydrogrindelaldehyde, erythrofordin, norerythrofordin, hedychilactone, hedychinone, phytol
Flavonoids	Apigenin, luteolin, rutin, quercetin, myricetin, baicalein, galangin, naringenin, hesperidin, catechin, wogonin, deguelin, rotenone, cyanidin, pelargonidin, epicatechin, epigallocatechin gallate, delphinidin, fisetin, silymarin, peonidin, petunidin, malvidin, isorhamnetin, kaempferol, tangeritin, epicatechin gallate, pachypodol, rhamnazin, naringin, eriodictyol, genistein, daidzein, glycitein, gallocatechin, coumestrol, biochanin A
Glucosinolates	Sinigrin, gluconapin, glucobrassicin, glucobrassicanapin, progoitrin, glucoiberin, gluconapoleiferin, glucocheirolin, glucoerucin, glucoberteroin, gluconasturtiin
Monoterpenes	Geraniol, limonene, terpineol, carvone, carveol, α-pinene, β-pinene, eucalyptol, linalool, myrcene, carene, citral, citronellal, citronellol, camphor, borneol, eucalyptol
Nonprotein amino acids	Alliin, methiin, propiin, isoalliin, etiin, butiin, *S*-allyl cysteine, djenkolic acid, ethionine, canavanine
Phenylpropanes	Caffeic acid, theaflavin, thearubigin, sesamol, rosavins, resveratrol, pterostilbene, piceatannol
Polyacetylenes	Panaxynol (falcarinol), falcarindiol, falcarinone, panaxydol, panaxytriol, panaxacol, dihydropanaxacol, capillin
Polyketides	Acetogenins (annonacin, uvaricin), erythromycin A, pikromycin, clarithromycin, azithromycin, amphotericin, bullatacin, tetracyclines, discodermolide, aflatoxin, aloenin, aloesin, barbaloin, anthraquinones
Sesquiterpenes	Farnesene, farnesol, artemisinin, caryophyllene, bisabolol, cadinene, vetivazulene, guaiazulene, longifolene, copaene, lactucin, parthenolide
Tetraterpenes	α-Carotene, β-carotene, β-cryptoxanthin, lutein, lycopene, phytoene, crocetin, crocin, annatto, phytofluene, sporopollenin, zeaxanthine, cryptoxanthine
Triterpenes, saponins, steroids	Squalene, β-sitosterol, lupeol, lanosterol, glycyrrhizin, liquiritic acid, glabrolide, ginsenosides, betulinic acid, ursolic acid, oleanolic acid, lantadene, lantanolic acid, lantic acid

Source: Reprinted from *Bioactive Foods in Promoting Health*: *Fruits and Vegetables,* Thompson, H. J., Vegetable and fruit intake and the development of cancer: A brief review and analysis, pp. 19–36, Copyright 2010, with permission from Elsevier.

Yet their presence in diets and subsequent absorption (some of them are not even digestible) in the body prevents the incidence of many diseases. The sheer number of diseases modulated by such agents indicates that they probably exert their effect at the cellular level. When such compounds occur in food and have demonstrable health benefits, they are called nutraceuticals. Some of the phytochemicals are closely attached to the structural framework of plants and are therefore not extractable using conventional solvent extraction methods but they are nonetheless biologically useful.

It is indeed difficult to evaluate these nutraceuticals and functional foods using conventional pharmacological methodology. Pharmacology is an integrative discipline that originated more than 500 years ago to identify therapeutics from natural product sources. In the nineteenth century, much of the work in pharmacology was based on the law of mass action (LMA), which demonstrated that compound effects were dose/concentration-dependent, which eventually lead to the receptor concept. Although more than a century old, this concept remains the key to understanding disease causality and drug action. The evolution of pharmacology in the twentieth century incorporated many of the translational technologies such as biochemistry, molecular biology, genomics, and bioinformatics, which in turn provided important insights into the mechanism of action of many therapeutic agents and the discovery of novel ones. It also increased the precision in understanding receptor function at the molecular level but the sophistication of modern pharmacology has also made drug development processes overtly reductionist. Modern pharmacology, however, seems ill prepared for the "newer" diseases such as neurodegeneration, depression, metabolic syndrome, cancers, obesity, etc. Science is only beginning to grasp the subtle and varied mechanisms involved in processes such as oxidation, inflammation, and immunity. It is the hope that the integration of newer technologies within a pharmacological context, where the health benefits of functional foods and nutraceuticals and their subsequent use in health care systems is determined by observed bioactivity, epidemiological evidence, and testable hypotheses rather than narrow correlation within the existing technology.

Modern drug discovery and development programs are based on careful analyses of evidence gathered from pharmacodynamic and pharmacokinetic studies of well-characterized chemical compounds, often called the active pharmaceutical ingredient (API). Indeed, the earlier contributions to therapeutics were based on the isolation of the "active constituents" of several medicinal plants. Such plant-derived phytochemicals differed from their synthetic counterparts only in the origin or source of the API. These natural products mimicked the synthetic compounds and were comparable to them both in precision of biological activity and toxicity. Later active fractions of plant extracts containing several chemical constituents were accepted and registered as phytomedicines but their acceptance was largely based on the ability to fit into the narrow construct of an "evidence-based medicine" that fits into Paul Ehrlich's original concept of "magic bullet" therapeutics. This concept envisages a "one target, one drug" paradigm and any natural product that does not readily show any "active constituent" was therefore regarded as a "dietary supplement," and therefore considered a relative of vitamins and minerals—in which case, their absence in diets should manifest in observable disease or sickness. But the phytochemicals in functional foods do not work either as "active pharmaceutical ingredients" or as vitamins and minerals that are essential for life. The complexity of the various biological systems that constitute life demands a systems approach to maintenance of health, prevention of diseases, and restoration of health, which shifts the focus of intervention from either the disease or the pharmacological agent to the restoration of the distorted equilibrium of biological systems.

Phytochemicals in functional foods therefore work through multiple pathways: (a) direct physiological action based on the pharmacodynamics and pharmacokinetic properties of individual constituents and their congeners; (b) synergy or additive effect with other food constituents to exert beneficial effects; (c) polyvalent or multifaceted activity to achieve desirable pharmacological effects; and (d) by network pharmacology in which a number of weakly active plant secondary metabolites in an extract may exert a potent pharmacological effect by acting on multiple targets without the presence of a highly bioactive compound.

The first pathway outlined above has been the focus of drug discovery programs in which natural products are extracted using multiple solvents and the most biologically active of the extracts are further fractionated to produce a pool of compounds that are subjected to sophisticated bioassays: *in vitro, in vivo*, and mechanism-based assays to select the most bioactive molecules. The active compound(s) believed to be responsible for the observed biological activity is isolated and chemically characterized. The active molecule is then subjected to a battery of tests to determine its selectivity, toxicity, and pharmacokinetics. This method is often referred to as "bioassay-guided" separation, and isolation of the active constituents leads to the identification of a candidate molecule for the drug development path. As many scientists will testify, only 1–1000 extracts from ethnomedically useful plants will yield pharmacologically significant molecules in *in vitro* tests. The number of active "hits" will further reduce by the failure of most positive compounds to show any bioactivity in animal models.

Functional foods and/or nutraceuticals have been found effective in addressing a number of health conditions, including the following:

1. *Anti-inflammatory and antiarthritic:* It has been established that the prevention and amelioration of chronic inflammation plays a pivotal role in the maintenance of optimum health. Inflammation itself is a natural defense mechanism and results from the body's natural response to tissue injury. Chronic inflammation, however, results in the excess production and release of several endochemicals, such as eicosanoids, C-reactive protein (CRP), tumor necrosis factor alpha, nuclear factor kappa-B, interleukins, cyclooxygenases, and lipoxygenases. The balance between pro- and anti-inflammatory agents can be distorted, which leads to persistent inflammation sometimes caused by even low levels of pro-inflammatory chemicals over a long time. The result is illness and certain diseases, including cardiovascular disease, cancer, and arthritis. Ginger (especially aged roots), bitter kola (*Garcinia kola*), turmeric, *Moringa*, *Andrographis*, licorice, garlic, and basil are among the food substances with proven anti-inflammatory properties.
2. *Antibacterial/antifungal effect:* Plants produce a variety of chemicals to defend themselves against bacterial and fungal infections. The phytochemical constituents found in many volatile oils from flowering plants, mint, clove, cinnamon, scent leaves, and orange peel are known to possess antimicrobial activity. The phytochemicals allicin from garlic, gingerols from ginger, and polyphenols from grain of paradise (*Aframomum*) have shown by various studies to have significant antimicrobial properties. Proanthocyanidins are responsible for the antiadhesion properties of cranberry. Consumption of cranberries will reduce the risk of urinary tract infections and will improve dental health.
3. *Antiviral activity:* Some phytochemicals bind physically to cell walls, thereby preventing the adhesion of pathogens to human cell walls and others cause disruption of viral envelope integrity or the replication of the pathogens in human systems.

Viruses are difficult to control in humans but several phytochemicals such as the biflavonoids from bitter kola (*Garcinia kola*), licorice chalcones, amygdaline from *Vernonia* species, ginger, *Olinia rochetiana*, *Andrographis paniculata*, and *Warburgia ugandensis* are known to prevent the development of many viruses.

4. *Antioxidant:* Many phytochemicals have antioxidant activity to protect human cells against oxidative damage and reduce the risk of developing certain types of cancer. Phytochemicals with antioxidant activity include allyl sulfides (onions, leeks, and garlic), ellagitannins, anthocyanins, and flavonoids (pomegranate fruits), carotenoids (fruits and carrots), flavonoids (fruits and vegetables), isoflavones (soy and pigeon pea), benzophenones, kolanone, and bioflavonoids of *Garcinia kola*, and polyphenols (tea, cocoa, and grapes). Another source of tissue oxidation is atmospheric (triplet) oxygen, which is a low-energy biradical (i.e., contains two unpaired electrons). However, during the metabolism of oxygen as well nitrogen, alterations can occur to produce highly reactive oxygen and nitrogen species that will react with and cause damage to biomolecules. Plant antioxidants have the ability to interrupt the generation of these reactive species. That is why the use of antioxidants also extends to topical applications.
5. *Hormone modulation action:* Isoflavones, found in soy and pigeon pea, imitate human estrogens and help to reduce menopausal symptoms and osteoporosis.
   a. Lycopene in tomatoes modulate the enzymes responsible for prostate inflammation.
   b. Phytochemicals from the bitter leaves, *Vernonia amygdalina* (West African bitter leaf), and *Gongronema latifolia* (Utazi) have antidiabetic properties.
6. *Enzymes stimulation:* Phytochemicals stimulate various enzymes that regulate many physiological processes, and a better understanding of their mechanism of action has enabled their application in medicine. Indoles, which are found in cabbages, stimulate enzymes that make estrogen less effective and could reduce the risk for breast cancer. Other phytochemicals, which interfere with enzymes, are protease inhibitors (soy and beans), terpenes (citrus fruits and cherries), and biflavonoids of bitter kola (*Garcinia kola*).
7. *Interference with DNA replication:* Saponins found in beans interfere with the replication of cell DNA, thereby preventing the multiplication of cancer cells. Capsaicin, found in hot peppers, protects DNA from carcinogens.
8. *Antiaging:* Human tissues degrade with time and cells lose their ability to regenerate themselves. Certain phytochemicals have shown remarkable ability to maintain optimum catabolic/anabolic balance. Among the best known are the glucans found in the mushroom, *Cordyceps sinensis* (syn.: *Cephalosporium sinensis*), which occurs naturally as an endoparasitic fungus that grows from the head of one type of subterranean caterpillar at high attitudes in the Qinghai-Tibetan plateau; graphinolides from *Andrographis paniculata*, and gisenosides from *Panax ginseng*. It has now been established beyond reasonable doubt that these food plants can prevent organ senescence associated with aging to produce new cells and stimulate the production of hormones that otherwise decreases with aging.
9. *Chronic metabolic diseases:* Metabolic disorders manifest in the development of many diseases such as abdominal adiposity, cardiovascular degeneration, and obesity, with its associated diseases such as diabetes, osteoarthritis, and hypertension. Diet has been shown to be an important factor in the pathogenesis of metabolic diseases.

Food substances with proven antidiabetic properties include *Vernonia* (bitter-leaf), *Gongronema* (utazi), *Ocimum* (scent leaf), fenugreek, cinnamon, garlic, *Aloe vera*, and bitter kola. In a study conducted in the Democratic Republic of Congo (Kinshasa), it was established that antioxidant nutrients found in vegetables could prevent chronic diseases, including type 2 diabetes mellitus (T2DM) and metabolic syndrome (Met S). In an evaluation on 244 T2DM patients (56.6% of females) and 48 ± 16 years, it was found that cassava leaves and dried red beans intake, rich in antioxidants, were protective factors against Met S presence, while being female, of high socioeconomic status, and physical inactivity are independent risk factors of Met S.[8]

10. *Digestive system dysfunction:* A healthy digestive system is important for maintaining health and preventing a vast array of diseases. The digestive system or gut is a long passage designed to break down and process food, absorb nutrients, and reject waste. When food is ingested, the gut operates like an assembly line in reverse, working efficiently only if the delivery of material to the next stage is coordinated closely with the optimum rate of process at that stage. Constipation arises when food remains in the colon for an extended period of time after digestion and it begins to putrefy. In this condition, microbes invade the food and it begins to rot within the body. This putrefaction process results in the production of toxic waste. If the toxic waste remains in the colon, the situation becomes a very hazardous condition for both the gut and other organs because much of the generated poisonous matter is taken up into the bloodstream. What this means, in effect, is that constipation actually gives rise to a process of self-poisoning or what is called "auto-intoxication." Many parts of the body are affected when the normal functioning of the gut is compromised by infections, physical obstruction, or biochemical disturbance. The health of the gut is guaranteed by a robust and remarkably reliable network of control systems, orchestrated by a range of neurochemical and endocrine responses reacting to the material in the gut, and managed by the complex circuitry and programs of the enteric nervous system. Plants used in the management of digestive deficiencies include various carminatives (sage, peppermint, chamomile, and nutmeg), aromatics (cardamom, aniseed, and cinnamon), antidiarrheal (guava, quercus, walnut, and roasted plantain), bulk laxatives (linseed, psyllium, wheat bran, and plant fibers), anthraquinone laxatives (aloes, senna, and cascara), emetics (squill and ipecacuanha), bitters (gentiana, buchu, bitter kola, centaury, wormwood, dandelion root, golden seal, utazi, and quassia), nausea (chamomile, peppermint, and ginger), ulcers and inflammations (licorice, bitter kola, myrrh, fennel, gotu kola, and marigold).

    Apart from their use in digestive system disorders, the effect of phytochemicals in the gastrointestinal system modulates many physiological body functions. The gut is not only a selective nutrient absorption system; it is also the most important signal transduction and information exchange system within the body. The gut is involved in nutrient recognition and signal transduction, and also acts as a neuroendocrine sensor, as well as an immunological recognition and presentation system. It is estimated that about 70% of the body's immune system is modulated by the gut.

11. *Neurodegenerative diseases:* It has been established that multiple factors are involved in the development of various neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease, multiple sclerosis, brain tumor, and meningitis. Chronic inflammation and oxidative imbalance are considered key components in the pathogenesis of such diseases. The observed differences in the incidence of

neurodegenerative diseases in different countries with markedly different dietary habits gave the first indication that food and environmental factors have a role in prevalence status of these diseases.

12. *Phytoestrogens:* The evaluation of foods rich in phytoestrogens indicates that apart from their general beneficial effects on women's health, they have enormous health benefits, including osteoporotic fractures, cardiovascular diseases, postmenopausal symptoms, certain cancers, and prostate enlargement.

1.3 How Do We Get Enough Phytochemicals?

Foods in their natural state contain a lot of phytochemicals and therefore are already part of our daily diet. In fact, most foods contain phytochemicals except for some refined foods such as sugar or alcohol. Other foods on the hand, such as vegetables, spices, teas, beans, fruits, and whole grains contain abundance of phytochemicals. Furthermore, herbs and spices can be selected and cultivated to yield specific phytochemicals for targeted physiological conditions. The easiest way to get more phytochemicals is to eat more fruits and vegetables. To maintain optimum health, it is recommended that apart from taking food for satiation, a daily intake of fruits and vegetables is necessary to provide sufficient supply of phytochemicals, minerals, vitamins, and fibers. Phytochemicals specific to certain plants are known to exert profound pharmacological activities and exhibit modulatory effects on specific genes. Among these agents are lycopene (tomato), capsaicin (red chilli), trigonelline, diosgenin, (fenugreek), 6-gingerol (ginger), ellagic acid (pomegranate), curcumin (turmeric), resveratrol (red grapes, peanuts, and berries), genistein (pigeon pea and soybean), diallyl sulfide (onions), *S*-allyl cysteine (allium), allicin (garlic), ursolic acid (apple, pears, and prunes), silymarin (milk thistle), anethole (anise, camphor, and fennel), catechins (green tea), eugenol (cloves), indole-3-carbinol (cruciferous vegetables), limonene (citrus fruits), β-carotene (carrots), and dietary fiber.[9]

Studies have shown that the gut microbiota of individuals consuming a Western diet are likely to be reduced as the lower digestive tract is seriously depleted of metabolic fuels, probably leading to a suboptimal gut microbial profile.[10] The most obvious and harmful consequences of reduced microbiota are malfunction, dysbiosis, and the often observed high levels of endotoxin in plasma (endotoxemia), which in both experimental and clinical studies is strongly associated with inflammation and risk of obesity and chronic diseases. It is well established that endotoxins are integral components of the outer membrane of Gram-negative bacteria like Enterobacteriaceae and Pseudomonadaceae, composed of proteins, lipids, and lipopolysaccharides (LPS). LPS, which is responsible for most of the biological properties of bacterial endotoxins, is known to have exceptionally strong ability to induce inflammation via the so-called Toll-like receptors 2 (TLR2) and 4 (TLR4).[10]

1.4 Raw versus Cooked Food

Many African functional foods are usually eaten raw as fruits, snacks, and vegetables. Raw food diets have been prescribed by some wellness programs as the best way to ensure

that the nutrients in plants are available in a manner that best delivers the phytochemicals. Many publications suggest that an exclusive vegetarian diet of raw plant materials, without meat or dairy products, can reverse the course of many diseases, including cancer, arthritis, obesity, hypertension, and diabetes. The advocates of the raw food diet recommend that we should eat our fruits and juice our vegetables for optimum effect. They claim that cooking food above 116°F destroys vital enzymes in the plants and reorder the natural structure of some of the nutrients. The counter-argument stresses the fact that most plant enzymes are in fact destroyed by stomach acids and are not generally available in raw foods after ingestion.

Phytochemicals are naturally present in many foods but sometimes are only available after limited processing. Simple chopping, crushing, or slicing of certain foods can make their nutrients more available; examples include garlic, cloves, onions, and several fruits. The nutrients in many others plants such as carrots, tomatoes, cruciferous vegetables, and leafy greens such as spinach and fluted pumpkins are more available or can only be released in a useable form after cooking. Some studies have indicated that a restrictive raw diet may make it difficult to meet the daily human requirement of calcium, vitamin D, and vitamin B_{12} and could cause menstrual irregularities and low bone mass and erode tooth enamel.

Caution should also be exercised when eating raw vegetables in tropical countries because of possible contamination with adhering microbes. In environments where food hygiene cannot be guaranteed, it may not be advisable to eat raw food; even fresh vegetables in salads are potential sources of foodborne toxins. Some plants, especially legumes and nuts, contain natural toxins or antigrowth factors, which are usually destroyed during cooking, and should therefore not be eaten raw: beans, peas, alfalfa sprouts, lentil sprouts, mung bean sprouts, and certain mushrooms. The International Centre for Ethnomedicine and Drug Development (InterCEDD, Nsukka, Nigeria) has developed a scheme to indicate the minimal processing required for most of the common foods. Phytochemicals in foods can be retained after short-term microwave drying, which can also destroy the adhering microbes. In cases of severely malnourished children, functional foods are used as therapeutic agents and therefore play a medicinal role. It has been noted that most fresh and raw whole vegetables should normally contain only minimal or undetectable levels of stimulants of TLR2 or TLR4.[11] However, certain raw and minimally processed vegetables (MPVs) are very sensitive to storage and might occasionally contain large quantities of bacteria and endotoxins; among these are bean sprouts, diced onions, and chopped root vegetables such as carrots and onion.[12]

Another dimension in the scientific evaluation of foods as medicine is the enormous differences often encountered in the receptivity of the body to different types of food among various races, ethnic groups, and closed communities. The common saying "one man's meat is another man's poison" is so true with regard to certain types of food. Cases of intolerance to cow milk (lactose intolerance) among certain individuals (especially Africans) and severe allergic reactions to nuts, fish, and some vegetables are quite common.

The overwhelming evidence on the therapeutic value of food raises a philosophical problem, which epistemologists call the "demarcation problem"—where does food for nourishment and satiation end and when does it become medicine? With numerous instances of "accidental therapy" that are known in medicine, where positive outcomes are observed even when the diagnosis and treatment are faulty or illogical, it is difficult to draw a hard line among food, health food, and phytomedicine.

1.5 Low Consumption of Animal Protein

Field studies in West and Central Africa revealed a predominance of vegetables and plant-based food in most African traditional diets. The exceptions were the pastoral communities, such as the Fulani of West Africa; Kenyan Nilotes tribes (Maasai, Samburu, and Turkana people of the lowland regions of the Rift Valley and the Kalenjin people who live in the highlands of East Africa); the Cushites, including Somali, Rendile, Borana, and Oromo tribes; Hamer of Ethiopia; the Beja tribes—the Hadendowa, the Bisharin, the Amar'ar, the Bani-Amir, and the 'Ababda—the Nuer and Dinka of Sudan; the Wodaabe and Tuareg; and other cattle-herding pastoral communities.

Consumption of beef, pork, and turkey has been linked to many inflammatory diseases. It has been shown that storage of such meat increases their content of TLR2 and TLR4 stimulants within a few days, even when stored at 5°C, and especially if exposed to air.[13] It has also been reported that the accumulation of TLR2 and TLR4 stimulants is minimized by storage of meat in its intact rather than minced forms, and when stored under a modified atmosphere, rather than exposed to air.[13]

It has even been suggested from the China Study that much of human diseases are traceable to the overconsumption of animal proteins.[14] The China–Oxford–Cornell Study on Dietary, Lifestyle and Disease Mortality Characteristics, conducted in 65 rural counties in China, was a comprehensive examination of dietary and lifestyle factors associated with disease mortality. The study compared the health consequences of diets rich in animal-based foods to diets rich in plant-based foods among people who were genetically similar. The study included a comparison of the prevalence of Western diseases (coronary heart disease, diabetes, leukemia, and cancers of the colon, lung, breast, brain, stomach, and liver) in each county, using 1973–1975 death rates. The study collected diet and lifestyle variables (ignoring all other factors) from inhabitants of the same counties approximately 10 years later, and found that, as blood cholesterol levels rose, so did the prevalence of "Western" diseases recorded in those counties in 1973–1975.

The authors suggested that most of the misinformation about nutrition has been deliberate falsification and further argued that "most, but not all, of the confusion about nutrition is created in legal, fully disclosed ways and is disseminated by unsuspecting, well-intentioned people, whether they are researchers, politicians or journalists," and that there are powerful industries that stand to lose a lot if Americans shift to a plant-based diet. They alleged that those industries "do everything in their power to protect their profits and their shareholders."

They maintained that earlier studies of nutrition (particularly the well-known Nurses' Health Study, which began in 1976) were flawed because they focused on the effects of varying amounts of individual nutrients among people who were consuming a uniformly carnivorous (animal-based) diet. They wrote that "hardly any study has done more damage to the nutritional landscape than the Nurses' Health Study," and that it should "serve as a warning for the rest of science for what not to do."

Available evidence suggest that a diet that is low in animal protein and that contains generous amounts of vegetables and fruits daily appear to offer some protection against many diseases, including cancers of the stomach, colon, and lung, and possibly against cancers of the mouth, larynx, cervix, bladder, and breast, several degenerative disorders, and metabolic diseases. Various types of vegetable-rich dietary plans exist and individual variations are as shown below.

Type of Vegetarianism	Dietary Habits
Fruitarianism	Eat only fruit products
Veganism	Abstain from all foods from animals, including dairy products
Lacto-vegetarianism	Like vegans, but eat dairy products
Lacto-ovo-vegetarianism	Like vegans, but eat dairy products and eggs
Pesco-vegetarianism	Like vegans, but eat dairy products, eggs, and fish
Semi-vegetarianism	Like vegans, but eat dairy products, eggs, fish, and poultry

1.6 Gluten-Free African Food Plants

Members of the Triticeae grass tribe (wheat, rye, and barley) and the Pooideae subfamily (oats) contain glutenoids, and a series of human disorders have been linked to exposure to glutenoids, particularly gluten (wheat), secalins (rye), and hordeins (barley). Gluten is the composite of two storage proteins, gliadin and a glutenin, conjoined with starch in the endosperm of these grains. Gluten gives elasticity to dough, helping it rise and keep its shape, and often gives the final product a chewy texture. However, some people suffer from gluten sensitivity, which is believed to induce inflammation and increase intestinal permeability. A disorder known as celiac disease (CD) or coeliac disease is characteristic of gluten sensitivity. Other gluten-related disorders include nonceliac gluten sensitivity (NCGS), wheat allergy, gluten ataxia, and dermatitis herpetiformis (DH). The clinical symptoms associated with gluten sensitivity include the following: fatigue, depression, encephalopathy/"foggy mind," lack of energy, diffuse abdominal pain, bloating, diarrhea, eczema and/or rash, undefined headache, numbness in the legs, arms, or fingers, joint pain, and many other manifestations. Currently, the incidence of gluten-related disorders is increasing in many parts of the world. Most of the gluten-containing crops are of Western origin and are the preferred crops whose flours are used in making bread and other staple foods. On the other hand, there are many alternative African grains and root crops that yield flours that are gluten-free. They include such crops as pigeon pea, Bambara nuts, chickpea, corn, hemp, maize, millets, oat, potato, quinoa, sesame, sorghum, amaranth, arrowroot, brown rice, buckwheat, acha, chia, soya, tapioca, teff, and African rice. Sorghum, for example is the fifth commonest grain in world and especially attractive due to its extremely high content of antioxidants,[15] low content of energy, and ability to resist heat-induced protein glycation,[16] but also due to its high versatility and cost-effectiveness.[10]

1.7 African Functional Foods in Commerce

The global market for functional food industry is believed to be more than 200 billion U.S. dollars in 2015, going by the BCC Research estimate of 176.7 billion in 2013 and with a compound annual growth rate (CAGR) of 7.4%. The global nutraceutical market alone was valued at $160.6 billion in 2013 and increased to $171.8 billion in 2014. The market is

expected to reach $241.1 billion by 2019, at a CAGR of 7% from 2014 to 2019. African medicinal plants are currently not major articles of trade in the global market. Only about 10% of over 5000 plant species used in traditional medicine in Africa have been commercialized in any significant manner, with less than 100 medicinal species traded on international markets. A recent review by Dr. Ben-Erik Van Wyk[17] showed that only four African medicinal plants were included in the four volumes of the *Selected Monographs of Medicinal Plants* published by the World Health Organization (WHO, 1999, 2003, 2007, 2009). These are *Aloe ferox* (vol. 1, p. 33), *Commiphora myrrha* (as *C. molmol*) (vol. 3, p. 247), *Harpagophytum procumbens* (vol. 3, p. 182), and *Prunus africana* (vol. 2, p. 246). When plants that occur in Africa and other regions of the world are included, the number of species can be adjusted to 12 out of the 118 species reviewed in the monographs. In the food sector, however, the continent has made a very substantial contribution to the major food crops of the world with many important species such as coffee, sorghum, oil palm, cow pea, millets, and cocoa. Many crops from Africa are highly valued as articles in international trade.[18] These figures indicate that enormous potential exists for the development of African indigenous functional foods as commercial products for the domestic and international markets.[19]

The presentations in the chapters that follow are on the fundamental role of functional foods selected from the vast biodiversity of the continent. Sometimes, the part used as food may be different from the plant part that contains the functional attributes. For example, mango juice contains all the essential nutrients in mango fruit, which does not vary significantly among the different varieties. But mango juice will not qualify as a "functional food" because the functionally relevant attributes are found in the peel and the leaves. Whereas the flesh is rich in energy, vitamin C, provitamin A carotenoids, minerals, and fiber, the peel is a source of phenolic antioxidant compounds, mangiferin, kaempferol, quercetin, and anthocyanins, mono- and diterpenes, fiber, and antioxidant minerals. Therefore, mango with the peel can be considered a functional food but the juice alone is not regarded as a functional food.

Nutrition itself continues to be a dynamic subject.[21] The scientific community dishes out recommendations on the health benefits of specific food ingredients that are sometimes contradictory. Some consensus is beginning to emerge as to what constitutes a healthy diet as part of a heathy living lifestyle.

The elements of a healthy diet include the following:

- Limiting fat intake to between 15% and 30% of total energy intake, and saturated fats to less than 10%.
- Carbohydrates should provide the bulk of energy requirements, between 55% and 75% of daily intake. But free (or added) sugars should remain below 10%.
- Daily intake of salt, which should be iodized, should be restricted to less than 5 g a day.
- The intake of fruits and vegetables should be at least 400 g a day.
- The recommended protein intake is 10%–15% of total daily intake.
- Avoid or limiting intake of red meat and preserved meat, egg yolk, organ meats like liver, kidney, brain, bone marrow, etc., whole milk, cream, cheese, ice creams, chocolates, etc., solid fats such as ghee, butter, etc., saturated oils, deep-fried foods, bakery products that are made with solid fats (high in trans fat) such as biscuits, cakes, pastries, doughnuts, butter rolls, etc.

Glossary

Biomarker: An objectively measured characteristic that acts as an indicator of normal biological processes, pathology, or responses to therapy.

Epigenetics: The study of heritable changes in gene function that occur without a change in the sequence of the DNA, for example, modification of chromatin proteins, such as histones, and DNA methylation.

FDA: The Food and Drug Administration (**FDA** or **USFDA**) is an agency of the United States Department of Health and Human Services. The FDA is responsible for protecting and promoting public health through the regulation and supervision of food safety, tobacco products, dietary supplements, prescription and over-the-counter pharmaceutical drugs (medications), vaccines, biopharmaceuticals, blood transfusions, medical devices, electromagnetic radiation-emitting devices (ERED), cosmetics, animal foods and feed, and veterinary products.

Functional food: Any food or food ingredient that may provide a benefit (which may be physical and/or mental) beyond the traditional nutrients it contains.

GRAS: Foods and other substances categorized by the USFDA as Generally Recognized as Safe. The GRAS designation implies that the chemical or substance added to food is considered safe by experts, and so is exempted from the usual Federal Food, Drug, and Cosmetic Act (FFDCA) food additive tolerance requirements.

Novel foods: Defined as a type of food that does not have a significant history of human consumption or is produced by a method that has not previously been used for food. For regulatory purposes, in Europe, it means "Foods or food ingredients that were not used for human consumption to a significant degree within the European Community before May 15, 1997."

Nutraceutical: Extracts of foods or isolated constituents claimed to have a medicinal effect on human health, which implies that the extract or food has been demonstrated to have a physiological benefit or provide protection against a chronic disease.

Nutrigenetics: The study of individual genetic variations, the ways in which they interact with dietary components, and their association with health and disease.

Nutrigenomics: The study of the molecular relationships between nutrition and the responses of genes, with the aim of determining effects on human health.

Phytochemicals: Plant-derived chemicals (usually secondary metabolites) with physiological or pharmacological effects when ingested as food.

Polyphenols: Phytochemicals with a chemical structure that includes multiple phenolic ring structures and double bonds.

Prebiotics: Indigestible dietary carbohydrates (and similar substances) that support the growth of beneficial intestinal bacteria.

Probiotics: Ingested live bacterial cultures with health-promoting benefits.

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2

Historical Introduction: The Role of Dietary Plants in Traditional Medical Care in Africa

Africa is endowed with a huge treasure of cultural and genetic resources, which is manifest in the varied use of plants for food and medicine. The peculiar geography of the continent has produced enormous biodiversity in its tropical forests, savannahs, the veldts, and the unique environments of sub-Sahara. It has no marginal oceanic trenches and subduction zones, so it lacks the extensive mountain ranges found in the Americas but much of the southern half of the continent rests on a high plateau close to 1000 m above sea level, which is broken only by the southern extension of the Great Rift Valley and the slightly lower basin of the Congo River. It has been suggested that it is the great latitudinal range that gives it an enormous variety of climates, and that it is this variability that is responsible for the continent's extreme diversity of ecosystems and biodiversity.[1] The continent is considered the cradle of human civilization with the oldest history of known human habitation. The ancient kingdoms and empires of Africa, such as Kmt (Egypt), Nubia, Ethiopia, Songhai, Bini, Oyo, Zimbabwe, Dogon, and Mende, as well as Nupe, Borno, Igbo-Ukwu, Mandingo, Jukun, Nri, and Somali, had extensively codified healing recipes. The history of healing arts in Africa can be traced back to ca. 3200 BC, during the reign of Menes, the first Pharaoh of ancient Egypt. Athothis, the son of Menes, was credited with the knowledge of many therapeutic preparations.[2] The honor of the first African physician, in a scientific sense, is accorded to the great Imhotep (c. 2650–2600 BC) who served in the Third Dynasty under King Djoser (Zhosa) as chancellor to the pharaoh and high priest of the sun god Ra at Heliopolis. Imhotep (Immutef, Im-hotep, or Li-em-Hotep, as his name has been written at various times; or Imuthes by the Greeks) was an accomplished architect, and the step pyramid at Saqqarah is among his numerous works. He was indeed a great ancient African polymath, whose official titles include

Chancellor of the King of Egypt
Doctor
First in Line after the King of Upper Egypt
Administrator of the Great Palace
Hereditary Nobleman
High Priest of Heliopolis
Builder, Chief Carpenter
Chief Sculptor, Maker of Vases in Chief
Great Poet

Imhotep was best known in history as a great architect and a renowned healer, who by 525 BC had become deified as the god of medicine. Another ancient African physician is the scholar and scribe Hesy-Re, who lived also about 2600 BC. According to the writer

Ghalioungui, Hesy-Re was the chief of dentists and physicians during the Third Dynasty, a period in African history usually associated with the building of the pyramids. During the same period in history, there was also the great healer Meri-Ptah.

These ancient African healers and those that lived after them had an elaborate *materia medica*, which consisted of mixtures of various herbs, animal parts, minerals, and clays. The *Ebers Papyrus*, one of the oldest in medical literature, listed several recipes used by ancient African healers. The list, however, was dominated by numerous food plants, in keeping with the belief at that time that "every disease to which men are liable is occasioned by the substances whereon they feed."[3] Even today, in traditional African medicine, there is no clear distinction as to when an herb ceases to be a health food and when it becomes a medicine. Many food plants have been used historically for therapeutic purposes, and medicines are not viewed as "necessary poisons." This is in contrast to Western orthodox medicine, in which drugs are seen as poisons, which when used in low doses and in a prescribed manner may cure diseases. Some of the plants used as dietary plants have functional roles in health care and are increasingly being recognized as "nutraceuticals" or dietary supplements in the Western system of medicine. Table 2.1 lists the food plants that have featured prominently as ingredients of remedies used in traditional medicine.

The African *materia medica* does not consist of dietetics alone, but includes many poisonous plants used for the treatment of diseases, for magic and rituals, and to caste spells on perceived enemies. Because of the inherent bias of modern pharmacology to the activity of substances with clearly defined and easily measurable biological activities, only few African healing herbs are recognized in modern pharmacopeias; the list includes Calabar bean (*Physostigma venenosum*), *Strophanthus*, areca nuts, kino, Salix, kola, the African periwinkle (*Catharanthus roseus*), and the devil's claw (*Harpagophytum procumbens*). It is interesting to note that in several instances, these are only African varieties of many "official" drugs. The African *Rauvolfia vomitoria*, for example, has a higher content of the antihypertensive alkaloid reserpine and the antiarrythmic drug ajmaline than the better-known species of the genus *Rauvolfia*. Another example is the willow plant, *Salix capensis*, which has been used in south-eastern Africa for centuries as a painkiller and antipyretic; it is known to contain esters of salicylic acid, a compound whose acetylated form is the universal analgesic, aspirin. The ginger cultivated in Nigeria is valued by consumers more than the Asian and Caribbean varieties. Although there is a large number of research publications available on the constituents and biological activity of medicinal plants from Africa, the development of therapeutic agents from African medicinal plants has remained a somewhat neglected subject. The study of African medicinal plants also has not been taken as seriously or documented as fully as in other traditional societies, such as the Indian and Chinese. Our knowledge of African medicinal plants is rather limited. The little available information is often fragmented and most African medicinal legends have become distorted by several centuries of continuous waves of invasion and conquest of various parts of Africa.

The documentation of medicinal uses of African plants is becoming increasingly urgent because of the rapid loss of the natural habitat of some of these plants due to anthropogenic activities. The continent is estimated to have about 216,634,000 hectares of closed forest areas with a calculated annual loss of about 1% due to deforestation; many of the medicinal plants become extinct before they are even documented. Africa has one of the highest rate of deforestation in the world, for example, Cote d'Ivoire and Nigeria have 6.5% and 5.0% deforestation per year, respectively; the global rate is 0.6%. Habitat conversion threatens not only the loss of plant resources but also traditional community life and cultural diversity, and the accompanying knowledge of the medicinal value of several

TABLE 2.1

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Abelmoschus esculentus (Malvaceae) Okra, okro, lady's finger	Vegetable, soup thickener	Fruit antioxidant, cardiovascular health
Acacia arabica Willd. (Mimosaceae) Egyptian Mimosa "Gabaruwa"	Leaves, fruits, and seeds are eaten	Treatment of diarrhea, dysentery, and abdominal pains
Acacia nilotica (Mimosaceae) Babul acacia	Gum used in food, leaves as fodder for domestic animals, flowers yield honey of good quality	Anti-inflammatory, antihypertensive, and antispasmodic activities
Acacia senegal (Mimosaceae) Gum Arabic	Fruits, resin, and gum are popular food in the Sahel region. The fruits are tasty, sweet-sour, yellow pulped, and the exudate is sold in food markets	Pulmonary disease, tuberculosis, dysentery, diarrhea, and antidote for food poisoning. Hemostatic and antiseptic
Adansonia digitata (Malvaceae) African baobab, monkey bread, tree of life, renala (mother of the forest)	Leaves, fruits, and seeds are edible. Fruit used for flour and drinks with distinct acidic or tart flavor, described as "somewhere among grapefruit, pear, and vanilla"	Fevers, skin diseases, malnutrition in children, colds
Aframomum angustifolium (Zingiberaceae)	Food decorations, spices and condiments	Stimulant, tonic
Aframomum corrorima (Zingiberaceae) Korarima, Ethiopian cardamom	Condiment, spice, flavoring drink	General tonic, carminative, and purgative
Aframomum melegueta (Zingiberaceae) Grains of paradise, alligator pepper	Fruits and seeds as spices and condiments, eaten with kola nut and garden egg as snacks	Seed oil is antibacterial, antifungal, carminative, analgesic
Agathosma betulina (Rutaceae) Buchu	Flavoring, tonic drink	Gastrointestinal and urinary tract infections. Antiseptic
Agave sisalana (Agavaceae; APG: Asparagaceae)	Sisal fibers are used to fabricate mats for food trays, fermented juice is alcoholic drink	Diaphoretic, diuretic, syphilis, pulmonary tuberculosis, and jaundice
Allium cepa L. (Liliaceae) Onion "Albasa"	Seasoning for soups and stews. Salad with vegetables	Antimicrobial, expectorant; stomachache, antinausea. In health soups for indigestion, hemorrhoids, and diarrhea
Allium sativum L. (Liliaceae) Garlic, "tafannuwa"	Soup ingredient, seasoning	Abdominal disorders, vermifuge, dyspepsia, cardiovascular health
Alocasia macrorrhizos (L.) G. Don ex Sweet (Araceae) Giant taro	Tubers yield starchy meal, leaves can be used as vegetables	Boiled stems are used as a laxative, chopped-up roots and leaves as a rubefacient, and juice from the petiole used for cough

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Amaranthus cruentus (Amaranthaceae) Amaranth	Various species used as vegetables dish. Cooked and used as ingredient in sauces and soups	Tapeworm expellant; fever, hemorrhage, anemia, or kidney dysfunction
Amaranthus hybridus L. (Amaranthaceae) Marog, smooth pigweed	The grain is toasted, milled, and powdered, and drunk as atole. Leaves are used as vegetable for soups and stews	A tea made from the leaves is astringent. It is used in the treatment of intestinal bleeding, diarrhea, excessive menstruation, and stomachache
Amaranthus spinosus (Amaranthaceae) Spiny amaranth	Tender and young plants are collected and cooked, steamed, or fried and used as vegetable	Hemorrhoids, expectorant, and to relieve breathing in acute bronchitis; externally for eczema, burns, wounds, boils, and earache
Amaranthus thunbergii (Amaranthaceae) Wild amaranth, pigweed	Leafy vegetable eaten fresh or dried; it is eaten with milk or fat in combinations with sorghum or maize	Potherb for constipation; wound healing
Ananas comosus (Bromeliaceae) Pineapple	Refreshing fruit; consumed fresh, cooked, juiced, and preserved; ingredient in many African cuisines. Proteases from the leaves and fruit used to tenderize meat	Leaves and fruits are used as ingredients in traditional medicine for various gastrointestinal disorders
Annesorhiza nuda (Aiton) B.L. Burtt (Apiaceae) Anise root	Vegetable	Carminative, stomachache
Annona senegalensis (Anonaceae) Wild Custard Apple	Leaves and flowers are used as seasoning. Fruit eaten. Infusion of young bark used as condiment with seeds of *Parkia filicoidea*	Infusions and decoctions of bark or root taken for intestinal worms. Dysentery and diarrhea
Arachis hypogeae (Leguminoseae, Fabaceae) Groundnut, peanuts	The seeds are used for food and as source of vegetable oil; eaten raw, boiled, or roasted, made into peanut butter, confectioneries, and snack foods, and are used for thickening soups or made into sauces to be eaten with meat and rice. In Nigeria groundnut is mixed with "gari" (coarse fermented cassava meal) and made into balls that are eaten as a snack	Pod extracts as galactagogue and for conjunctivitis. Macerations of peeled seeds are drunk to treat gonorrhea, macerations of the seed coats against syphilis and ophthalmia. Sap of ground leaves and seeds is used for ear-drops infection, diuretic, female infertility, and tooth decay
Aspalathus linearis (Fabaceae) Rooibos tea, redbush	Caffeine-free tea substitute	Stimulant, antioxidant, fermented beverage used as sliming agent. Acts on adipocyte

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Asparagus africanus (Asparagaceae)	Vegetable, salads	Guinea worm, hemorrhoids, laxative, eye inflammation
Asparagus flagellaris (Asparagaceae)	Substitute for asparagus	Inflammations, hair growth ointment, infertility treatment
Asparagus officinalis L. (Asparagaceae)	Cultivated in less tropical parts of the continent for its tender young expanded shoots (spears) which are eaten lightly cooked	The herb, rhizomes, and seeds are used as a tonic, antifebrile, antirheumatic, and diuretic medicine
Athrixia phylicoides DC. (Asteraceae) Zulu tea	Refreshing tea	Treatment of boils, acne, infected wounds; Inflammation and infection of the throat
Balanitas aegyptica Del. (Zygophyliaceae) Desert date tree, aduwa	Leaves and flowers are vegetables, fruits and seeds are eaten, refreshing drink	Astringent, anthelmintic, antidiabetic, antioxidant
Bauhinia reticulata DC. (Caesalpiniaceae) Camel's foot tree "Kargo"	Leaves, bark, or twigs as food flavors	Expectorant, diarrhea
Biden pilosa (Compositae, Asteraceae) Black Jack	The fresh or dried tender shoots and young leaves are used as a leaf vegetable especially in times of food scarcity	The aerial parts are used as antimalarial antibacterial, antidysenteric, anti-inflammatory, antimicrobial, diuretic, hepatoprotective, and hypertension remedy. Extract of the plant showed a high inhibition of prostaglandin synthesis in an *in vitro* assay for cyclooxygenase inhibitors
Brachiaria deflexa (Schumach.) C.E. Hubb. ex Robyns (Poaceae) Guinea millet	The soft grains are ground and used as flour to make cakes and fritters	Gastrointestinal disorders, diabetic food
Brassica rapa (Brassicaceae, Cruciferae) Chinese cabbage, neep crops	Introduced vegetable, consumed boiled, in soups, fresh in salads, or stir-fried in special dishes	Essential oil used as traditional remedy for colds and aches
Bulbine frutescens (L.) Willd. (Asphodeaceae) Ibhucu	Vegetables, health drink	Fevers, wound, insect stings
Cadaba farinose Forsk. (Capparidaceae) "Bagayi"	Edible fruits, leaves, twigs, or as food flavoring	Infusion of bark or leaves for abdominal swelling and intestinal worms
Cajanus cajan (Leguminosae) Pigeon pea	Beans used as staple in West Africa	Sickle cell anemia
Caloncoba echinata (Achariaceae)	Fruits used for refreshing drink. Seeds are aromatic	Leprosy, skin diseases

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Capsicum annum L. (Solanaceae) Capsicum pepper "Barkono"	Fruit and seeds are widely used as a pungent; spice in many cuisines	Embrocation, antimicrobial, vermifuge, expectorant, carminative
Capsicum frutescens L. (Solanaceae) Shrubby capsicum	Spice and condiment for West African pepper soup	Carminative, expectorant, embrocation, antimicrobial
Carapa procera (Meliaceae) Monkey kola	Fruits and leaves are edible	Vermifuge, skin care
Carica papaya L. (Caricaceae) Paw-paw, papaya "Gwanda"	Fruits eaten, fruit juice, and soothing and delicious drink	Leaves for malaria mixture, seeds for abortion, ascaricide
Carpobrotus edulis (Aizoaceae)	Fruit and leaves are edible—raw, cooked, dried for later use, or made into pickles, chutney	Astringent, antiseptic, treatment of diarrhea, dysentery, and stomach cramps
Cassia occidentalis L. (Caesalpiniaceae) Coffee Senna	Young leaves and unripe fruit pods added to cooked cereal dishes. Seeds are used in a beverage. Root is condiment and is eaten to enhance appetite	Dyspepsia and diarrhea; intestinal worms and stomachache
Catha edulis (Celastraceae) Khat, bushman's tea	Masticatory	Stimulant, general tonic, anti-inflammatory
Celosia argentea (Amaranthaceae) Celosia, sokoyokoto	Leafy vegetable used in soups and stews	Antioxidant, anti-inflammatory, gastrointestinal disorders
Celosia laxa Sch. & Thonn (Amaranthaceae) "Nannaho"	Leaves and whole plant are used in soups or added to various grain and vegetable-based foods	Vermifuge, reduces biliousness and nausea
Centella asiatica (Apiaceae) Indian pennyworth	Vegetable	Circulatory system disorders. Gastrointestinal disorders, mouthwash, ulcers, cancers, etc.
Chrysophyllum albidum (Sapotaceae) African star apple	Delicious but somewhat tart-tasting fruits	Antihistamine, antihypertensive
Citrullus colocynthis (Cucurbitaceae) Watermelon	The refreshingly juicy and sweet flesh of the mature fruit is used in diet	Diuretic
Citrullus lanatus (Cucurbitaceae) Egusi melon, egusi	Edible seed are made into pulp and added as soup thickener; roasted and eaten as nuts; fermented seeds are used as condiments and flavoring agent	Fruits are purgative; diuretic and used to treat diarrhea and gonorrhea
Citrus aurantifolia Swingle (Rutaceae) Citron, orange	Fruit is eaten. Pulp and rind are used as seasoning; dried rind used as tea admixture	The rind and leaves are antiseptic. Anti-inflammatory

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Citrus aurantium L. (Rutaceae) Sour orange	Used in fruit salad, rind in teas	Antiseptic, carminative
Cleome gynandra L. (Brassicaceae) Spider plant	The tender leaves, young shoots, and occasionally flowers are eaten boiled as potherb, relish, stew, or side dish	Anemia, lowers blood cholesterol, anti-infective
Cocos nucifera (Arecaceae) Coconut	Delicious fruits, part of daily diet in many parts of the world. The "water" makes a refreshing drink, the oil is used in many dishes, the endosperm is eaten as snacks	Called the "the tree of life" in the Philippines because all the parts of the plant are useful. The "water" is used as an antidote for poisoning and used as liquid rehydration agent. The copra oil is an emollient and the oil from the fresh endosperm called virgin coconut oil (VCO) is used for many health-optimizing functions
Coffea arabica (Rubiaceae) Coffee	A highly appreciated beverage, taken roasted and powdered	Aphrodisiac, anorexic, antidotal, cardiotonic, central nervous system (CNS) stimulant, counterirritant, diuretic, hypnotic, lactagogue, and nervine. Coffee is a folk remedy for asthma, tropine poisoning, fever, flu, headache, jaundice, malaria, migraine, narcosis, nephrosis, opium poisoning, sores, and vertigo
Coffea canephora (Rubiaceae) Coffee robusta	Robusta coffee is used as a stimulant drink	Endocrine, muscular/skeletal, blood system, metabolic system, digestive system, nervous system, and sensory applications
Cola acuminata (Sterculiaceae) Kola nut, "gworo"	Fruit is a masticatory and is chewed for its stimulant, appetite-depressive and thirst-assuaging effect	CNS stimulant, cholagogue, and diuretic activities
Cola nitida A. Chev. (Sterculiaceae) Kola nut	A masticatory used interchangeably with *C. acuminata*	Antifatigue, CNS stimulant, and diuretic
Colocasia esculentus (Araceae) Taro	The leaves and stalks are used as a leafy vegetable and potherb for soups and sauces, or as relish. The tubers are cooked for fufu	The leaves are used for arterial hypertension and liver affections
Combretum micranthus (Combretaceae) Kinkeliba; opium antidote	Leaves are edible and used as "caffeine-free" tea	Respiratory disorders, gastrointestinal diseases, CNS stimulant, opium antidote

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Cordia abyssinica R. (Boraginaceae) "Alilliba"	Fruits and flowers are sweet and used as food flavorings. Bark and fruit infusions serve as appetite stimulants	Flowers or fruits are used as vermifuge. Bark infusion for diarrhea and dysentery
Corchorus aestuans (Malvaceae) West African mallow	The leaves are widely eaten as a vegetable. It is consumed as leafy vegetable in a mucilaginous sauce	Treatment of urethral discharge, headache, a tonic, carminative, and febrifuge
Corchorus olitorius (Malvaceae) Jew's mallow	Used as a leafy mucilaginous vegetable. The cooked leaves form a slimy sticky sauce, comparable to okra. In West Africa, the soup is found suitable for easy consumption of starchy balls made from cassava, yam, or millet	The leaves are used for constipation and seeds in Nigeria as a purgative and febrifuge
Costus afer (Costaceae) Ginger leaf	The succulent stem peat is edible and chewed as snack and to quench thirst in the field	Antihypertensive, aphrodisiac ingredient, anti-inflammatory
Croton gratissimum Burch (Euphorbiaceae)	Tobacco substitute, used as eating forks among girls of the "Ju, 'hoan" tribe, of Northeastern Namibia after the onset of menstruation	Upper respiratory pain and for intercostal neuralgia. Leaves for coughs and inflammations
Cucumis africanus (Cucurbitaceae) Wild cucumber	The leaves are eaten as a cooked vegetable by many tribes in its area of origin. Nonbitter fruits serve as a source of water and are eaten as a vegetable. In Madagascar, only the fruits are eaten	Plant parts used for diabetes, fruit protein has antitumor activity. The seeds contain glycoproteins (momorcharins α and β) with abortifacient, immunosuppressive, and antitumor activity
Cucumis anguria (Cucurbitaceae) West Indian gherkin	Leaves and seeds are eaten; they are cooked and eaten in the same manner as pumpkin leaves	Kidney stones, pesticide, stomachaches
Cucumis sativus (Cucurbitaceae) Cucumber	An introduced crop, the immature fruit used in salads, either with the skin or peeled. Fruits are sliced or cut into pieces and served with vinegar or a dressing	Used in many recipes for fevers; fruits are given to children to treat dysentery. The seed has some anthelmintic property
Cucurbita maxima (Cucurbitaceae) Pumpkin	Leaf used a vegetable; seeds and whole fruits cooked as vegetable	Soup used for stomachache, fresh leaves for intestinal infections and kidney problems and to expel tapeworms

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Cucurbita moschata (Cucurbitaceae) Musk pumpkin	Fruit and leaf vegetable, the flowers are also consumed. The cooked fruit is popular in pumpkin pie	Leaves used for dermatitis, fruit is anthelmintic, and also applied to skin infections and inflammations
Cucurbita pepo (Cucurbitaceae) Courgette	They are eaten as a vegetable, either boiled or fried or stuffed. Mature fruits are rarely eaten	Used as a poultice to treat burns and inflammations and as a cooling compress to treat headache and neuralgia
Cucurmis melo L. (Cucurbitaceae) Wild sweet melon	Leaves, seeds, and fruits are eaten. Unripe fruit cooked as vegetable and in soups. Seeds are fermented and made into soup condiment	Fruit or seeds are taken for hemorrhoids and diarrhea. Seeds are chewed as an emollient. Antimicrobial
Curcuma longa (Zingiberaceae) Turmeric	Young shoots and young rhizomes can be eaten fresh as a spicy vegetable. Dried rhizomes are used in cuisines	Anti-inflammatory, stomachic, stimulant, and blood purifier, and to treat liver complaints, biliousness, and jaundice
Cyclopia genistoides (Fabaceae) Honey bush	Refreshing tea, potherb	Antioxidant, erectile dysfunction, chemopreventive
Cymbopogon citratus (Poaceae) Lemongrass	Soup ingredient, used in stews and as tea	Carminative and anticholeric properties and gastrointestinal disorders and the oil is used as a massaging agent against rheumatism
Cynara cardunculus (Compositae) Globe artichoke	Imparts sweet taste to food. Sugar substitute	Treatment of liver dysfunction, and as a diuretic and antiatherosclerotic
Cyperus esculentus L. (Cyperaceae) Tiger nut	The rhizomes are chewed and used for the preparation of the white, jelly-like, tiger nut milk	The oil is considered superior to olive oil and it is anticholesterolemic
Cytisus scoparius (Fabaceae)	Flowers are edible, coffee substitute, condiment	Cardiotonic, cathartic, diuretic, emetic, and vasoconstrictor
Dacryodes edulis (Burseraceae) Butter fruit tree	The oil-rich pulp is eaten after softening by immersion in hot water for 2–3 min, or by roasting in firewood ash	Leaves are ingested to treat disorders of the digestive tract, toothache, and earache
Detarium microcarpum (Leguminosae–Caesalpinioideae) Sweet dattock	The fruit is sweet and commonly eaten fresh, while the pulp is used in the preparation of cakes and couscous. The pulp is used as a substitute for sugar	Used as diuretic and astringent; antioxidant properties; treatment of rheumatism, venereal diseases, urogenital infections, hemorrhoids, caries, biliousness, stomachache, intestinal worms, and diarrhea, including dysentery; malaria, leprosy, and impotence

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Detarium senegalense (Leguminosae–Caesalpinioideae) Tallow tree, detar	The greenish and sweet-acidulous fruit pulp is edible, and can be eaten raw or cooked.	Tonic for anemia and fevers; fruit pulp for kidney pain, spinal tuberculosis, syphilis, cough, rheumatism, and leprosy
Dialium guineense (Fabaceae) West African tamarind	The red/orange fruit pulp has a sweet-sour, astringent flavor similar to baobab, but sweeter. It is peeled and eaten raw or used to prepare a refreshing drink	Leaves and fruits used in traditional medicine for various diseases
Digitaria exilis (Poaceae, Gramineae) Fonio, acha	A staple food in various parts of West Africa. Fermented for porridge and beverages	Convalescence meal, helps lactating mothers and for diabetes
Dioscorea dumetorum (Dioscoreaceae) Bitter yam	The subterranean tubers are eaten cooked or dried and prepared for flour production	Used for the treatment of diabetes. The wild variety is poisonous
Diospyros mespiliformis and related species (Ebenaceae) Ebony, African ebony	The fruits are used in the production of fruit juice and alcoholic drinks. They can be ground into a flour, which is sometimes an ingredient of porridge. Seeds are edible	Treatment of malaria, pneumonia, syphilis, cough, bronchial diseases, tuberculosis, syphilis, and leprosy; and applied externally to wounds and ulcers
Dovyalis caffra (Hook.f. & Harv.) (Salicaceae) Kei-apple	Used in preparation of jam, dried, liqueurs, sweets	Chest and cardiac problems, amenorrhea
Echinochloa colona (Poaceae) Jungle rice	Famine cereal, used in porridge in the Sahel region. Young shoots eaten as vegetable	Used for gastrointestinal disorders; cardiovascular health
Elaeis guineense (Arecaceae, Palmae) Palm tree, oil palm tree	Almost all parts of the palm tree are edible. Yields palm oil, kernel oil, husks that are parts of African cuisines	The oils are used in various traditional medicines. The palm heart is used to treat gonorrhea, menorrhagia, and perinatal abdominal pain; antiemetic, laxative. Leaf sap is used for skin affections and roots as analgesic
Eleusine coracana (L.) Gaertn. (Graminae) Finger millet	Used in cereals and porridge	The seed is used as a prophylaxis for dysentery. Treatment of infections
Ensete ventricosum (Musaceae) Enset	The enset corm is cooked fresh and consumed in a way similar to potato. A starchy food is produced from the pseudostem, corm, and stalk of the inflorescence	Leaves are used to stimulate labor or induce abortion. To treat hepatitis and other liver complaints

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Eragrostis tef (Poaceae, Gramineae) Teff, lovegrass	Teff flour is mainly used to prepare "injera," a thin, flat, pancake-like bread, made from dough fermented for 2–3 days	Gluten-free flour; meal for diabetes; dried sheaths as dietary fiber. High calcium and lysine content
Eucalyptus globulus (Myrtaceae)	Yields Eucalyptus oil, leaves are used as spice	The leaves and oil are used in traditional medicine for the treatment of various diseases, including cough and chest infections; as an expectorant, febrifuge, tonic, astringent, antiseptic, hemostatic, and vermifugal properties
Ficus sur (Moraceae) Bush fig	Young leaves are cooked and eaten as a vegetable	The latex is used for treating wounds, toothache, eye problems, general body pain, lung and throat problems, gonorrhea, and as an antiemetic. Root is used for treatment of cough, sore throat, diarrhea, stomach pain in babies, chest pain, infertility, uterine pain, gonorrhea, edema, and as an emmenagogue and emetic
Garcinia kola (Clusiaceae) Bitter kola	Edible bitter nut used as masticatory	Antihepatotoxic, anti-inflammatory, antiviral, and antioxidant
Gnetum africanum (Gnetaceae) Eru	Vegetable in soups and stews; eaten raw, shredded and used in salads	Treatment of liver diseases, piles, and high blood pressure and for enlarged spleen and sore throat, and as a purgative
Gongronema latifolium (*Marsdenia latifolia* (Benth.) K. Schum) (Apocynaceae) Utazi	Vegetable, sharp-bitter and sweet and widely used as a leafy vegetable and as a spice for sauces, soups, and salads. The leaves are used to spice locally brewed beer	Appetite stimulant and tonic; antidiabetic, an infusion of the aerial parts is taken to treat cough, intestinal worms, dysentery, dyspepsia, and malaria
Grewia bicolor (Malvaceae, Tiliaceae) Bastard brandy bush	The sweet, mealy fruit pulp is eaten fresh, or dried as candy. Juice from the fruit is drunk fresh, added to porridge, fermented into beer, or distilled into liquor. The mucilaginous leaves and fibers from the leaf are used as thickening agent in sauces. Fresh leaves are used as teas	The bark is used as a vermifuge, diuretic, and laxative, and to treat boils and sores, intestinal inflammation, and syphilis. The bark is said to possess both inebriating and tranquillizing effects, and is also taken to counter fatigue

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Griffonia simplicifolia (Leguminosae)	Added to palm wine for punch and bitter taste. Sap from stems drunk to quench thirst	Antiseptic, aphrodisiac, sickle-cell anemia
Hibiscus sabdariffa (Malvaceae) Zobo, rosette	Vegetable, beverage, dried red calyces are commonly used to prepare a tea, drunk hot or cold and sweetened as needed. It is a sour-tasting, refreshing drink, very popularly mixed with ginger	Antihypertensive, treatment of colds, toothache, urinary tract infections, and obesity
Hoodia gordonii (Asclepiadaceae) Queen of the Namib	Famine food and thirst quencher	Natural appetite suppressant, treatment of circulatory system disorders, diabetes, hypertension, digestive system disorders, peptic ulcers, and endocrine system disorders
Hyphaene coriacea Gaertn. (Arecaceae, Palmae) Doum palm	The sap is used as refreshing palm wine. Fermented to yield an alcoholic beverage	Digestive system disorders; wound healing
Icacina oliviformis (Icacinaceae) False yam	Edible tubers used as famine food	Abortifacients, genital stimulants/depressants; kidneys, diuretics; oral infections
Ipomoea aquatic (Convolvulaceae) Kangkong	Young shoots and leaves of kangkong are used as a leafy vegetable. Can be stir-fried, steamed, boiled for a few minutes or lightly fried in oil and eaten in various dishes	The sap is used as an emetic, purgative, and sedative, and flower buds are applied to ringworm
Irvingia gabonensis (Irvingiaceae) Ogbono, African bush mango	Soup thickener, condiment, cooking oil; the juice can be fermented to produce a quality wine with 8% alcohol content	Diarrhea, treat hernias, yellow fever, and dysentery; obesity and male sexual dysfunction
Lablab purpureus (Fabaceae) Lablab	Leaves are used as vegetable. The young green pods and immature seeds are eaten boiled	Cardiac problems, tonsillitis, and diabetes. It is antihypertensive, anticholesterolemic, antispasmodic, digestive, hypoglycemic, and anti-inflammatory
Lactuca serriola L. (Asteraceae, Compositae) Lettuce	Lettuce is grown for its leaves, usually eaten raw as a salad with a dressing or plain. Occasionally, lettuce is used as a cooked vegetable, especially in lowland areas	Used as aphrodisiac, painkiller, antispasmodic, carminative, diuretic, emollient, expectorant, febrifuge, and sedative

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Lagenaria siceraria (Cucurbitaceae) Calabash gourd	Young, tender, nonbitter fruits are used as a vegetable. Cut or peeled, and then boiled for 10–15 min until soft	Diabetes, inflammation
Lannea acida A. Rich. (Anacardiaceae) "Faru"	Fruits, gum, and leaves are edible. Fruits have an acid to resinous taste and can yield alcoholic beverages	Bark and leaf infusions and decoctions are used in the treatment of diarrhea, dysentery, stomach complaints
Lannia microcarpa (Anacardiaceae) African grape	Young leaves are eaten	Leaves and stem bark used in traditional medicine for mouth blisters, rheumatism, sore throat, dysentery, inflammations; as a cathartic and as a dressing on boils
Launaea taraxacifolia (Compositae) Yanrin, African lettuce	Yanrin is used among the Yoruba people of Nigeria to prepare "efo yanrin" soup. The leaves are eaten fresh as a salad or cooked in soups or sauces	Febrifuge, fertility-enhancing herb, ingredient in treating snake-venom-induced temporary blindness
Lippia javanica (Burm.f.) Spreng. (Verbenaceae) Fever tea	Tea, health drinks	Malaria, fevers, cardiac diseases
Manihot esculenta (Euphorbiaceae) Cassava	The tubers are source of the edible cassava meal, the West African "garri" and tapioca flakes. The fermented starch yields "fufu." It is a staple food in Africa. Leaves used as vegetables	The young leaves, rich in protein and vitamins, are eaten as vegetables. Some varieties are cultivated especially for their edible leaves
Maerua angolensis DC. (Capparaceae Capparidaceae) Bead-bean tree	Leaves and roots are eaten; condiment	Digestive system disorders, immune system disorders, infections/infestations, muscular–skeletal system disorders, neoplasms, nervous system disorders, pain, skin/subcutaneous cellular tissue disorders
Mangifera indica L. (Anacardiaceae) Mango	The fruits are edible. The juice makes a refreshing drink, which can be concentrated into many food items	Leaf and bark infusions are used to treat stomach disorders and diarrhea. Stem, fruit, and seed kernels are used as anthelmintic
Manilkara mochisia (Baker) Dubard (Sapotaceae) Lowveld milkberry	Used in jam, jelly, and drinks	Diarrhea, back pain, emetic

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Massularia acuminate (Rubiaceae)	Tooth cleanser, chew stick	Used in medications for arthritis, rheumatism, dropsy, swellings, edema, gout; kidneys disorders, antidiuretics; liver diseases, for normalization of menstrual cycle; antiabortifacient, and venereal diseases
Momordica charantia L. (Cucurbitaceae) Balsam pear, bitter gourd	Leaves or sometimes whole aerial parts are cooked and used as vegetable. Bitter fruit is eaten when cooked. Seeds sometimes chewed as appetite enhancer	Aerial parts used for treatment of diarrhea, diabetes, and intestinal parasites. Leaves for syphilis and rheumatism and as an abortifacient. Root decoction for stomachache, dysentery, and hemorrhoids
Mondia whitei (Apocynaceae) White ginger	Refreshing drink with a pronounced vanilla-like odor and taste like a mixture of licorice and ginger	Malaria, aphrodisiac, bronchitis, diuretic
Morinda lucida (Rubiaceae) Brimstone tree	Tea, potherb	Hypertension, dysentery, malaria, fever
Moringa oleifera (Moringaceae) Horseradish tree	Leaves and young fruit pods are cooked as vegetables and are added to soups. Young roots are used as seasoning. Seeds yield edible oil	All parts of the plant are used as medicinal agents. Leaves as tonic and antimicrobial agent. Roots, leaves, and gum are used for inflammations, intestinal worms, diarrhea, and bilious congestion. Water purification
Mucuna pruriens (Leguminosae) Lacuna bean, black velvet bean	Soup thickener	Parkinson's disease, sexual dysfunction, general tonic
Musa L. (edible cultivars) (Musaceae) Banana, plantains	The fruits are staple in most parts of Africa. It is used either raw or cooked, or prepared into various dishes. It may be processed into starch, chips, puree, or beer	The young unfolded leaves are used for chest pains and as a cool dressing for inflamed or blistered skin. The sap is used for treatment of gonorrhea, dysentery, and diarrhea. The juice of the root is febrifuge and restorative
Myristica fragans (Myristiaceae) Nutmeg tree	Culinary spice	Carminative, postpartum medication, hypnotic
Nasturtium officinale (Brassicaceae, Cruciferae) Watercress	Young shoots with leaves are used as a pungent garnish and eaten raw in salads. Cooked as vegetable or made into watercress soups. In Africa it is mainly eaten by expatriate communities	Antiscorbutic stimulant and as a laxative
Ocimum gratissimum (Lamiaceae) Scent leaf	Culinary spice, vegetable	Febrifuge, malaria treatment, diabetes, anti-inflammatory

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Olea europaea L. subsp. *africana* (Mill.) P.S. Green (Oleaceae) Wild olive	Condiment, jam	Emollient, leaves used as fever medicine
Oryza glaberrima Steud (Poaceae) African rice	In West Africa, this species of rice is preferred to the Asian rice for its taste and culinary properties	Eaten raw for diarrhea and gastrointestinal disorders
Parinari curatellifolia (Chrysobalanaceae) Hissing tree	Pleasant strawberry-like-tasting fruit and the oil is used in food and cosmetics	Treatment of cataracts and earache. Immune system and skeletal muscle diseases
Parkia biglobosa (Leguminosae) African locust bean tree, dawa-dawa	Fermented as food condiment for seasoning sauces and soups	Infusions of leaves, bark and fruit pods are prepared for stomachache, dysentery, diarrhea, and hemorrhoids. Seeds are used for hypertension
Pelargonium graveolens L'Hér (Geraniaceae) Rose geranium	Flavoring agent, condiment for soups	Ingredient in potherb for colds
Pennisetum glaucum (Poaceae) Pearl millet, babala	Used as snack foods, health foods, breakfast cereals, popcorn; traditional beers	Diarrhea, respiratory diseases, snake bite, cough
Pennisetum purpureum (Poaceae) Elephant grass	Food condiment. Very young and tender inflorescences are eaten as vegetable. Seeds eaten as cereal	Psoriasis, deafness, colic, toothache, wound healing, fiber source. Constipation, cough
Persicaria senegalensis (Polygonaceae) Silver snake root	The tender leaves are eaten cooked as a vegetable	As an ingredient for the treatment of syphilis. In Nigeria and Ethiopia, pounded leaves are applied to swellings, syphilitic sores, and skin affections
Phaseolus vulgaris L. (Leguminosae) Kidney bean, common beans	The mature dry seeds of common bean are eaten worldwide as a pulse and the immature pods and seeds as occasional vegetable. Considered "meat of the poor"	Various parts of the plant are used as carminative, diuretic, cardiotonic, digestive, and emmenagogue
Phoenix dactylifera (Arecaceae, Palmae) Date palm	The fruits are edible, yields tasty juice and syrup, which forms part the staple diet in North Africa	The trunk yields a gum used in treating diarrhea. The fruits are a demulcent, expectorant, and laxative, and also for treatment of respiratory diseases and fever
Physalis angulata (Solanaceae) Gooseberry, cut-leaf ground cherry	The fruit is eaten as a snack, but much of the fruits may cause dizziness. The leaves are eaten as a salad regardless of the bitter taste	Whole part used for sterility. The leaves are analgesic and used to treat skin ailments, and for smallpox pustules, whitlow lesions, infected scarification wounds and rheumatic pain, and to relieve muscular stiffness and pain

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Piper guineense (Piperaceae) Ashanti pepper, bush pepper	Spice for flavoring sauces and soups	Seeds for coughs, sore throat, and respiratory infections. Carminative and antibacterial. The leaves are used to regulate the menstrual cycle and an ingredient in remedies for female infertility. The roots are listed for gonorrhea, bronchitis, syphilis, and colds
Plectranthus esculentus (Lamiaceae, Labiatae) Kaffir potato	Cooked like yams and potato. The farinaceous tubers are eaten cooked, sometimes raw, or pickled	The leaves have been used for boosting immune system, and for digestive system disorders. Enterobiasis, tapeworm expulsion, headache, stomach pains
Poga oleosa (Rhizophoraceae) Inoi nut, poga tree	The sweet fruit pulp is edible. The seeds can be eaten fresh or after roasting and often added to sauces as condiment	Painkiller, to soothe toothache. Seed oil is taken as purgative, treatment of gonorrhea, and as a massage oil
Polygonum plebeium (Polygonaceae) Small knotweed	Eaten as a vegetable in Malawi, cooked with potatoes and groundnuts	Used for stomach complaints
Portulaca oleracea (Portulacaceae) Purslane	Leafy vegetables for soups, preparation of "rigla" sauce in Egypt and Sudan	Diuretic, to treat rheumatism, gynecological diseases, and fever; sedative, analgesic, cardiotonic; urinary tract, intestinal worm infestation, as a tonic and choleretic, to treat dysentery, ulcers, eczema, and dermatitis
Prosopis africana (Leguminosae, Fabaceae) African Mesquite	Leaves and flowers are edible. The fermented seeds are used as a food condiment	Antidiarrhea, diuretic, and used to treat gonorrhea, tooth, and stomachache, dysentery, and bronchitis
Pterocarpus osun (Leguminosae, Fabaceae) Camwood	Vegetable, food dye	Leaves and stem as ingredient in traditional medicines against sickle-cell disorder and amenorrhea
Pterocarpus soyauxii (Leguminosae, Fabaceae) African padauk	Edible vegetable with a peculiar taste and aroma	Fevers diarrhea, anti-inflammatory, female health disorders
Pycnanthus angolensis (Myristicaceae) Wild nutmeg	The bark is pounded and added to palm wine. The oil is not edible	Bark decoction is purgative and antidote to poisoning; for leprosy and stomachic

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Ricinodendron africanum Müll.Arg. (Euphorbiaceae) Groundnut tree	Much valued for its edible oil, extracted from the seeds and a paste made by crushing dried kernels is sometimes used as a thickening agent for soups and stews	Used for treating constipation, cough, dysentery, rheumatism, rickets in children, edema, elephantiasis, fungal infection, blennorrhea, painful menstruation, and threatened abortion
Ricinus communis (Euphorbiaceae) Castor oil plant	Fermented seed used as soup flavoring agent	Abortifacient, purgative, and external application as emollient
Rumex abyssinicus (Polygonaceae) (Sorrel)	The tender shoots and leaves of *Rumex abyssinicus* are edible and widely used as a vegetable. They have an acid taste and are eaten fresh or cooked, alone or together with other vegetables	Treatment of jaundice and related liver diseases, scrofula, stomachache, neckache, and low blood pressure. And as teniafuge. Externally as a wound dressing, hemostatic, and depurative
Saba comorensis (Apocynaceae) Rubber vine, bungo	The fruit pulp is edible and for preparation of refreshing sour drink	Oral care, thrush, anti-infective, anti-inflammatory
Saba senegalensis (Apocynaceae) Saba, liane saba	Fruit is edible, pleasant sour taste. In Senegal, the leaves are prepared in sauces and condiments as an appetizer with a salty taste	The leaves are eaten to stop vomiting. Bark decoctions are taken for dysentery, diarrhea, and food poisoning. Crushed leaf infusion has hemostatic/antiseptic action. The latex is used for pulmonary troubles and tuberculosis
Sabicea calycina (Rubiaceae)	Added to palm wine	Laxative, treatment of senile dementia
Saccharum officinarum (Poaceae) Sugarcane	Sweetener, sugar source	Bagasse and cane residues used in traditional medicine for cough, dysentery, and skeletal muscle diseases
Sacoglottis gabonensis (Humiriaceae) Bitterbark tree	The fruit is edible, sweet, and tastes like banana bread. It is mainly eaten by children and used to make an alcoholic drink. Stem bark used as palm wine additive, claimed to prolong the shelf life of the wine, add potency, reduce foaming, and impart a bitter taste	Aphrodisiac, to treat fever, diarrhea, gonorrhea, and abdominal pain, and sometimes used to treat hypertension and diabetes
Sarcocephalus latifolius (Rubiaceae) African Peach	Chewstick, beverage	Used for malarial fever, anemia, and atonic dyspepsia
Sceletium tortuosum (Aizoaceae) Kanna	A masticatory, often used for spiritual purposes	A mood enhancer, sedative, analgesic, for toothache and stomach pains, and appetite/thirst suppressant

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Schwenkia guineensis Syn. *S. america* (Solanaceae)	A potherb used for pregnant women and babies. Roots and stems are used as chewing sticks for cleaning the teeth	Sinusitis, conjunctivitis, rheumatism, arthritis, stomach problems, hernia, and gonorrhea
Scelerocarya birrea (Anacardiaceae) Marula fruit	The marula fruits are highly aromatic and can be eaten fresh or used in making juices, jams, and alcoholic beverages, such as amarula and tombo	Used in traditional medicine for the treatment of diabetes, dysentery, and snake and scorpion bites. An infusion of the bark is used to wash infants as a treatment for malaria or inflammation
Sesamum indicum (Pedaliaceae) Sesame, benniseed	The seed, paste, and oil are utilized in the preparation of many foods	Various plant parts are used in traditional medicine. Mucilaginous crushed leaves or leaf sap are used to treat fever, cough, and sore eyes and head lice; facilitate childbirth, treat dysentery and gonorrhea, snakebites, and malaria
Sideroxylon inerme (Sapotaceae) White milkwood	The fruits are eaten and the dried roots are chewed	Bark and roots are used to cure broken bones, to treat fevers, to dispel bad dreams, and to treat gall sickness in animals
Siphonochilus aethiopicus (Schweinf.) BL Burtt (Zingiberaceae) Wild ginger	Used in sauces, condiments, spices, flavorings	Antidiarrhea, dysentery; laxatives, vermifuge
Sphenostylis stenocarpa (Hochst. ex A. Rich.) Harms (Leguminoseae) African yam bean	Beans and tubers are edible food. The bean can be milled to produce a meal. Snack food	Considered a good nutrient for its high protein, mineral, and vitamin content. Antioxidant, treatment of alcohol intoxication
Spinacia oleracea (Amaranthaceae) Spinach	Cultivated as leafy vegetable	Carminative, febrifuge, hypoglycemic and laxative; urinary calculi; inflammation of the lungs, liver, and kidney
Solanum aethiopicum (Solanaceae) African eggplant	The immature fruits are eaten raw or cooked as vegetables in stews. The leaves and shoots are used as a cooked vegetable	Roots and fruits are used as a carminative and sedative; the bitter cultivars are used to treat diabetes, colic, and high blood pressure
Solenostemon rotundifolius (Poir.) J.K. Morton (Lamiaceae) Zulu round potato, amadada	Vegetable	Child birth, otitis, stomachache, hepatitis

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Sorghum bicolor (Poaceae) Guinea corn	Edible grain used as staple in many parts of the continent	The seed extracts are used for hepatitis, and decoctions of twigs with lemon against jaundice; leaves and panicles are decoctions against anemia. Sheaths of the red cultivar is an effective hemoglobin regenerating tonic
Sphenocentrum jollyanum (Menispermaceae)	The edible fruit is taken as fatigue snack	Aphrodisiac and general tonic; antihypertensive, antitumor, and anti-inflammatory
Strychnos spinose (Loganiaceae) Monkey orange, Kaffir orange	The edible fruits are delicious and the pulp is used for jams and spreads. The seeds are not edible	The unripe fruit contains strychnine, a powerful CNS stimulant and has been used to counter the respiratory depression caused by snake venom
Sutherlandia frutescens (L.) R. Br (Leguminosae, Fabaceae) Cancer bush	A very palatable plant with high nutrition value; used as appetite stimulant and animal feed	Used in traditional medicine for a variety of illnesses; anticancer, antiviral, antidiabetic, antitussive
Synsepalum dulcificum (Sapotaceae) Miracle berry	The sweet-acid pulp around the seeds is eaten and used to sweeten palm wine. The taste of sweetness remains for about 2 h in the mouth	Sweetener for diabetics, obesity, antioxidant
Talinum triangulare (Portulacaceae) Water leaf, poor man's vegetable	Vegetable for soups, stews, and potherbs	Antidiabetic, anti-inflammatory, measles, immune booster, and anemia
Tamarindus indica (Leguminosae) Tamarind	The ripe fruit of the sweet type is usually eaten fresh, whereas the fruits of sour types are made into juice, jam, syrup, and candy	Ingredient in cardiotonic and antidiabetic medicines. Also against asthma and amenorrhea and as febrifuge. Leaf extracts exhibit antioxidant activity in the liver
Telfairia occidentalis (Cucurbitaceae) Fluted pumpkin	A very popular vegetable used in many soup cuisines. Leaf and seed vegetable. The tender shoots, succulent leaves, and immature seeds are cooked and consumed as a vegetable	Used in potherbs for anemia, prenatal care, and cardiovascular disorders
Tetracarpidium conophorum (Euphorbiaceae) African walnut	The seeds are eaten raw, roasted, or cooked. The leaves and young shoots are eaten with rice	The aerial parts are used as ingredients for traditional stomachache remedy. Seeds used for mouth odor removal
Tetrapleura tetraptera (Leguminosae)	Soup flavoring, general tonic, and condiment for postpartum diet	Fevers and malaria, anticonvulsant, arthritis and other inflammatory conditions, asthma, diabetes mellitus, hypertension, and epilepsy

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Thaumatococcus danielli (Marantaceae) Miraculous fruits	Food sweetener, used for sweetening of palm wine, sour fruit desserts, etc.	Sedative, tonic, and fermented for colic
Theobroma cacao (Malvaceae, Sterculioideae) Cocoa	Globally favorite beverage	Anemia, inflammatory diseases
Tribulus terrestris (Zygophyllaceae) Bullhead	Leaves eaten as vegetables	A decoction is used in treating impotency in males, nocturnal emissions, gonorrhea, and urinary incontinence; for painful urination, gout, and kidney diseases. The plant has shown anticancer activity
Trichilia dregeana Sond. (Meliaceae) Umkhuhlu, natal mahogany	Vegetable	Abortifacient, diarrhea, backache
Trichilia emetica Vahl (Meliaceae) Umkhuhlu, natal mahogany	Vegetable	Emetic, diuretic, gastrointestinal disorders
Trigonella foenum-graecum (Meliaceae) Fenugreek	Seeds and leaves are used as a culinary spice. Ground or whole; roasted fenugreek seed with its nutty taste combined with flavors are used in several dishes	Antidiabetic diet. The seeds are edible and have been used in remedies for rheumatism, chronic cough, enlargement of the spleen and liver, and as a general tonic
Tulbaghia violacea Harv. (Alliaceae) Wild garlic	Condiment, culinary herb	High fever, cancers, headache, stomachaches
Tylosema esculentum (Leguminosae) Marama bean	Marama seeds are eaten boiled or roasted by the people in the Kalahari; it is a delicacy among other peoples in southern Africa	Leaves and roots are employed in traditional medicine as general tonic, subcutaneously for cellular tissue disorders
Uapaca guineensis and related species (Phyllanthaceae) Sugar plum	The sweetish edible pulp, which can be eaten raw. Its taste resembles that of dried prunes or avocado. In Nigeria, the pulp is made into a refreshing drink	Used extensively in traditional medicine; treatment of malaria, cancer, dysentery, diarrhea, stomachache, and venereal diseases
Urtica dioica (Urticaceae) Stinging nettle	The leaves are edible as a soup condiment. coloring, curdling agent, and in refreshing drink. Young leaves—cooked as a potherb and added to soups, etc.	Used as antiasthmatic, antidandruff, astringent, diuretic, galactogogue, hemostatic, and hypoglycemic remedy. Also used to treat anemia, excessive menstruation, hemorrhoids, arthritis, rheumatism, and skin complaints
Uvaria chamae (Annonaceae) Finger root	Condiment	Jaundice, inflammation, dysentery, antimicrobial preparations

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Vangueria infausta Burch. (Rubiaceae) False medlar, wild medlar	The tough brown elastic skin of the ripe fruit encloses a brown edible mealy pulp, which is sucked and the skin and seeds discarded	Roots and leaves used for treatment of malaria, pneumonia, stomachache, and ringworms. Leaves used for toothache and body swellings
Vangueria madagascariensis (Rubiaceae) Common wild medlar	The fruit is edible and used to add flavor to beer and other beverages. The ripe fruit pulp has a pleasant chocolate-like flavor	Unripe fruits used for inflammation; roots as anthelmintic
Vernonia amygdalina (Compositae) Bitter leaf	Bitter vegetable, soup ingredient, and tea	Hypertension, obesity, diabetes. The leaves are ingredients in purgative enemas, diuretic mixtures, anthelmintic preparations, and topical lotions for parasitic skin diseases
Vigna radiate (Leguminosae, Fabaceae) Mung bean	Mung bean seeds or flour are used in a variety of dishes, including soups, porridge, snacks, bread, noodles, and even ice cream. In East Africa, mung bean is most commonly consumed as whole seeds boiled with cereals such as maize or sorghum	Eaten as convalescence vegetable. The seeds are said to be a traditional source of cures for paralysis, rheumatism, coughs, fevers, and liver ailments
Vigna subterranean (Leguminosae) (Bambara groundnut)	Used in several cereal/starch-based preparations: Dried seeds are sometimes roasted and ground into flour	Seeds for venereal diseases and cataract. Leaves are applied to abscesses and infected wounds, sap is applied to the eyes to treat epilepsy, and the roots as aphrodisiac
Vigna unguiculata (Leguminosae, Fabaceae) Cowpea, black-eye bean, black-eye pea	Staple food used as cereal and pounded as starchy dough "fufu." The mature seeds are the preferred pulse in most parts of Africa and can used in a variety of dishes	The leaves are chewed to treat tooth ailments, powdered carbonized seeds are applied on insect stings, the root is used as an antidote for snakebites and to treat epilepsy, chest pain, constipation and dysmenorrhea, and externally as poultice to treat swellings and skin infections
Vitellaria paradoxa (Sapotaceae) Shea butter tree	Edible oil used for cooking and cosmetics	Ointment for rheumatic pains and boils. Decoction of the bark to facilitate labor
Vitex doniana (Lamiaceae) Black plum, West African plum	Fruits, leaves, and seeds are edible. Cooked young leaves are used as vegetable. The blackish sweet pulp is used to make jam. A beverage is made from the fruit juice, and fermented for alcoholic liquor and wine	Used widely in traditional medicine. Root decoction is used to treat ankylostomiasis, rachitis, gastrointestinal disorders, and jaundice. For pains, colic, and kidney problems

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Warburgia salutaris (Canellaceae) Pepper-bark tree	Fresh or dried leaves can be used in various dishes or tea to add an agreeable aroma and peppery taste	Resin carminative. The inner bark is used as treatment of malaria, colds, chest complaints, coughs, diarrhea, muscle pains, stomachache, and general body pains
Warburgia ugandensis (Canellaceae) East African greenheart	All parts have a hot peppery taste. Fruit is edible. The leaves and seeds are used for flavoring for soups and sauces	Antifungal, a remedy for stomachache, constipation, toothache, cough, fever, muscle pains, weak joints, and general body pains
Withania somnifera (Solanaceae) Ashwagandha	Occasional vegetable, tea, and potherb	Used in several traditional medicines in East Africa; as diuretic and detoxifier, antigonorrhea, and in the treatment of cough, asthma, and epilepsy; also as narcotic, hypnotic, aphrodisiac, liver tonic, purgative, and diuretic, and for the treatment of tuberculosis, senile debility, nervousness, rheumatism, furuncles, sores, dropsy, cough, and hiccup
Xanthosoma sagittifolium (Araceae) New cocoyam	The cormels and the leaves are cooked for various starchy dishes. The corms are used for animal feeds or dried and peeled and grounded to flour	The plant is applied topically against burns, boils, and tumors. The leaves and inflorescences are used as potherb for stomachache
Ximenia caffra (Olacaceae) Large sourplum	The bitter/sour fruits are eaten raw, refreshing with an almond-like scent. Or soaked in cold water and the skin and kernel are removed by pressing them out and the resulting porridge is mixed with pounded tubers as a dish. The fruits are also used for making jam	Oil used for body hygiene and sterility in women. The roots are used to treat abscess, severe stomachaches or colic, and against malaria, cough and bilharzia; as a remedy for syphilis, hookworm, chest pains, and generalized body pain
Xylopia aethiopica (Annonaceae) Ethiopian pepper	The fruits of *Xylopia* are used as soup condiment and spice	It is a common ingredient in several African traditional remedies. Given to women after childbirth as a general tonic and to promote healing and lactation, or to promote fertility; fruit is used as a remedy for stomachache, bronchitis, biliousness, and dysentery. Carminative and anticonvulsant
Zaleya pentandra (Aizoaceae)	Used as vegetable in arid conditions, flavoring agent	Infections, antiparasitic, analgesic

(*Continued*)

TABLE 2.1 (*Continued*)

Important Food Plants Used Historically in Traditional Medicine

Plant (Family)	Culinary Use	Medicinal Application
Zanha africana (Sapindaceae) Velvet-fruited zanha	Fruits are edible; peeled and the sweet fleshy yellow pulp eaten raw in small quantities. The seed is discarded. Fruits are mostly eaten by children and herdsmen among the Hehe, Luguru, and Nyamwezi. With a pleasant taste comparable to the taste of apricots. Nectar plant for honey bees	Root decoctions are used to treat headache, convulsions, and abdominal pain. Powdered root bark is added to tea or porridge to cure constipation, impotency, and helminthiasis. Root bark extracts are used to treat fungal infections
Zea mays	Maize is cultivated throughout the continent as a staple food. Eaten fresh on the cob, boiled, and simply roasted. The grain is usually ground and the meal is boiled into porridge or fermented into beer	Decoction of the styles or the leaves has been used in the treatment of urinogenital diseases, jaundice, and fever. Charcoal made from the culms is included in medicines to treat gonorrhea; an infusion from the burnt cob is used to wash wounds and for measles
Zingiber officinale (Zingiberaceae) Ginger	Ginger is used extensively worldwide as a culinary plant; in teas and as a savory and spice in many dishes	Used in African folk medicine as a carminative, diuretic, and antiemetic. It is one of the commonest ingredients in the preparation of remedies for gastrointestinal distress, liver diseases, fevers, and hypertension

endemic species. The vegetation of Africa can be classified into a number of phytochoria, that is, regions within which a substantial proportion of the plants are endemic, following the schemed proposed by White.[4] These include the (a) Mediterranean North Africa, (b) the Cape region of South Africa, (c) tropical Africa, and (d) Madagascar. Within tropical Africa, the major ecosystems are (i) forests, (ii) seasonal tropical vegetation (which consists of woodland, bushland and thicket, grassland, shrub lands), (iii) deserts, (iv) montane and Afroalpine ecosystems, (v) wetlands, (vi) lakes, and (vii) coastal vegetation. The majority of the plants found in Africa are endemic to the continent, with the Republic of Madagascar having the highest rate of endemism of 82%. The island contains over 12,000 species in its original forest areas, and 4900 of these species are found only on this island.[5] There is therefore an urgent need to document not only the uses but also the constituents and pharmacological activity of these plants. Over 5000 plants are known to be used for medicinal purposes in Africa, but only a few have been described or studied. This book provides an overview of the small fraction of the species that have been scientifically investigated.

African medicinal plants are considered here from two viewpoints: as sources of biologically active compounds and as elements in the complex equation of healing. At first glance, the two aspects may appear very different and even conflicting, but a closer inquiry will reveal a common ground in the two modes of medicinal plant utilization in traditional African medicine. We have included information on the physical characteristics of the plants, including size, shape, color, texture, and taste which have traditionally served as important criteria in their selection for therapeutic purposes. We are aware that a significant proportion of plants were selected on the bases of their physical resemblance to an organ of the body which is akin to the folk healing system called the "Doctrine of Signatures" ascribed to various medical traditions ranging from American Indian to ancient Chinese.

Many people are beginning to appreciate the enormous benefits derivable from the simple, mostly vegetable-based diet often associated with the African cuisine. The simplicity of the African diet is not dictated by poverty. Some affluent people living in developed countries have elected by choice to subscribe to the simple vegetarian-based lifestyle of rural African with incredible results on their health. When a British health blogger, Ella Woodward, was diagnosed with postural tachycardia syndrome, a rare disease that baffled her doctors, she was able to restore her health by only a simple change of her diet from the processed Western diet to a more natural lifestyle, similar to the diet of rural Africans. She was informed that her illness breaks down the immune system, but she was not told how, exactly, to treat it. She swapped out the processed ingredients she was accustomed to for more natural versions, and started developing plant-based recipes on a blog she called *Deliciously Ella*. Just over a year later, her health improved remarkably and she got a healthy following, as well as the fastest-selling debut cookbook ever in the United Kingdom. Therefore, beyond the centrifugal effect of rural poverty and the impact of the Western lifestyle in urban areas, the ingredients used in traditional African diets could be harnessed to good effect to reduce the disease burden inherent in the transition from a sustainable rural economy to precarious urban dwelling with a diminished nutritional base.

While working in Africa during the Second World War and in the 1950s, the British surgeon Denis Parsons Burkitt (February 28, 1911–March 23, 1993), better known for his observational study on the etiology of a pediatric cancer that bears his name (Burkitt's lymphoma), noticed that many of the noninfectious chronic diseases that were common in Britain were rare among Africans who were following a traditional lifestyle.[6] He wrote a book, *Don't Forget Fibre in Your Diet*,[7] which was an international best seller. The examples

he cited included coronary artery disease, varicose veins, diabetes, appendicitis, and even colon cancer.[8] Burkitt suggested that these "Western" diseases were largely due to a high-fat, low-fiber diet. He was eventually dubbed "the Fiber Man" for his insistence on the importance of a low-fat, high-fiber diet. These so-called Western diseases as identified by Burkitt remain the major causes of death and disability in the United States, Europe, and Australia. It has also been argued that arthritis, the number one cause of disability in the United States, has a dietary component. Some physicians from the United States believe that osteoarthritis is due to "wear and tear" on the joints,[4] yet osteoarthritis is relatively uncommon in Africa, where most of the population does most of its work by hand.[5]

According to Burkitt, the Western diseases are easy to prevent but hard to cure. As he put it, if people are constantly falling off a cliff, you could place ambulances at the foot of the cliff or build a fence on the top of the cliff. He argued that modern science is placing too many ambulances at the foot of the cliff. Burkitt emphasized the importance of fiber in the diet and the dangers of fat: "the frying pan you should give to your enemy. Food should not be prepared in fat. Our bodies are adapted to a Stone Age diet of roots and vegetables."

But Africans, like most of their counterparts in other developing countries or the so-called emerging nations, are abandoning these traditional diets and are showing an increasing high demand for a more Western diet, which could have a more detrimental effect on the health of the continent than malnutrition and hunger. Malnourishment in the form of overeating as well as undereating is not usually associated with a continent plagued by high levels of malnutrition and famine but the nutritional transition to Western-style overnutrition is expected to increasingly clog up health care systems and arteries in the developing world, including Africa. As Richard King puts it, the biggest threat to world food security is not availability of enough food for the teeming population. Instead, the real crunch is likely to come from the changing dietary preferences from people in some large emerging countries.[9] Economic growth, urbanization, and rising affluence are increasingly bringing with them higher demand for convenient, processed foods, for meat, and for dairy products—in short, a more Western diet. Changing diets bring significant social challenges, introduction of new diseases to the continent, and rising increase in the incidence of noncommunicable diseases. Studies have shown that metabolic diseases such as obesity tend to be concentrated in the middle classes—those who lead more sedentary lifestyles and consume more processed foods.[10]

It has been observed that in the last few decades, the number of deaths from noncommunicable diseases in developing countries has already exceeded those in developed countries.[11] Fat is no longer just a developed-world problem. Obesity, once thought to be a disease of developed countries, is fast becoming a crisis in Africa. According to the Overseas Development Institute, in a report published in 2015, more than one-third of the world's adults are overweight and that almost two-thirds of the world's overweight people are found in low- and middle-income nations.[12] The number of obese or overweight people in developing countries rose from 250 million to almost 1 billion in under three decades, and these rates are rising significantly faster than in rich nations.

Moreover, obesity is associated with an increased risk for many of these chronic conditions, including heart disease, hypertension, arthritis, and diabetes mellitus. In South Africa, it has been estimated that nearly two-thirds of the population is overweight and, unlike in the developed world, the problem afflicts more women than men. Incredibly, 69.3% of South African females display unhealthy levels of body fat and more than 4 in 10 are clinically obese (defined as having a body mass index [BMI] higher than 30).[13] These figures suggest that South Africa has nearly double the average global obesity rates, and according to another report has become the world's third fattest nation.[14] Studies among

Nigerian women have clearly illustrated that there are distinct geographic patterns in the combined prevalence of overweight and obesity, as well as the role of demographic, socioeconomic, and environmental factors in the ongoing nutritional transition in the country.[15] One major tool to address this trend and design appropriate intervention is better understanding of the contribution of African dietary plants to health.

Fortunately, there are indications that switching back from Western diets to traditional African meals that are low-fat and high-fiber may reverse the incidence of some of the diseases caused by Western diets as has been observed by the reduction in the risk of colon cancer by an American who made such a switch.[16]

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3

Major Nutraceuticals of African Origin

3.1 Introduction

Nutraceuticals are naturally derived phytochemicals with potential health benefits and without the characteristics of being essential nutrients. *Functional foods* are foods that contain these nonessential substances with potential health benefits. Although several compounds that are derived from animal and synthetic sources when added to natural foods to enhance their physiological activity are regarded as "nutraceuticals," the term is restricted to plant-derived substances that enhance the functionality of food beyond its normal nutritive value. Several variations in the general definition of functional foods exist but the generally accepted definition is that of the Food and Nutrition Board of the U.S. National Academy of Sciences, which defines functional food as foods that provide health benefits beyond basic nutrition.[1] Nutraceuticals are therefore the substances that occupy the intermediary place between functional foods and drugs.

A fundamental concept in the use of functional foods is that of rational polysupplementation, which involves the strategic integration of multiple nutraceuticals with potential complementary mechanisms for improving treatment outcomes and optimizing health. It will include food substances that contribute to the daily requirements of essential micronutrients, vitamins, and minerals; as well as phytochemicals such as glycosaminoglycans; fibers; unsaponifiable fractions of plant oils; methylsulfonylmethane; *S*-adenosylmethionine; undenatured and hydrolyzed collagen-like preparations; lignans; stilbenes; conjugated linoleic acids; tocopherols and coenzyme; phytoflavonoid and other polyphenolic compounds found in fruits, vegetables, spices, teas, and nuts; and other phytonutrients that occur in trace amounts in food.

What are nutraceuticals? The Foundation for Innovation in Medicine (New York, United States) defined nutraceutical as "any substance that may be considered a food or part of a food and provides medical or health benefits including the prevention and treatment of disease."

It has become a major area of biomedical research and practice that seeks innovative and nonpharmacological solutions to the prevention and treatment of diseases, as well as the optimization of health. Developments in molecular biology, physiological chemistry, and human nutrition have improved our understanding of disease pathophysiology and the basic molecular mechanism(s) of complex diseases such as cancers, diabetes, cardiovascular disease, HIV/AIDS, and diseases of overt inflammation, including neurodegenerative diseases (AD and PD). The strategies for the prevention of such diseases increasingly require the use of nonprescription prophylactic agents, such as vitamins, dietary antioxidant factors, extracts and natural products from food plants, medicinal plants, and fruits. They have demonstrated the potential ability to prevent or reverse the promotion or progression

of the diseases (in which inflammation, and cellular and redox signaling mechanisms play major roles). The other nondisease application of nutraceuticals and functional foods is in the optimization of health, especially in the prevention of premature aging and minimizing the effects of environmental pollutants on the immune system.

Nutraceuticals are therefore functional food ingredients with established specific health or medical benefits. For the purposes of this book and to bring some order to the varied definitions, the term "functional foods" will be restricted to describe items used as part of a diet or dietary supplement that are beneficial to health and the term "nutraceuticals" will be used to define ingredients derived from diets that have demonstrable health benefits. Of course, no rigid line exists between what constitutes functional food and what can be defined as nutraceutical. Examples of these are the health benefits observed in diets containing soluble fiber, isoflavones, proanthocyanidins, lycopene, resveratrol, catechins, omega-3 fatty acids, flavonols, monomeric and polymeric flavan-3-ols, biflavonoids, and phenolic acids (Table 3.1). As in most natural product-derived medicinal agents, the distinction may depend entirely on the form, preparation, and method of presentation of the food substance and the intended use. Typical examples include the following.

3.2 Polyphenols

Phenolics are one of the most widely occurring classes of compounds found in nature. They are molecules with one or more aromatic rings and at least two hydroxyl groups. They range from simple monomeric compounds with one or two phenolic rings to complex tannin-like compounds, with several aromatic rings. Several thousands have been isolated and their structures characterized, with many of the compounds showing remarkable biological activities and being almost devoid of adverse effect or toxicity.[2] Plant phenolics include phenolic acids, coumarins, chalcones, stilbenes, hydrolyzable and condensed tannins, lignans and lignins, as well as flavonoids such as myricetin, quercetin, kaempferol, isorhamnetin, and luteolin. The dimeric and polymeric phenolics include anthocyanins, biflavonoids (especially the *Garcinia kola* biflavanones), and flavanolignans.

The identification of polyphenols as a major class of nutraceuticals has provided much of the needed interphase to bridge the potential disconnect between food and nutrition science and health sciences.[3] Their contribution to the effect of certain diets that contain vegetables and fruits that are rich in polyphenols has been established in many studies.[4] A comparative study in which flavanol-rich beverage that was standardized with regard to its flavanol content was compared to a low flavanol control drink that was identical in terms of caloric load and macronutrient and micronutrient content, differing only in flavanol content, has been published.[5] The study clearly established that the consumption of certain dietary flavanols is causally linked to increases in flow-mediated dilation (FMD), a validated prognostic parameter (surrogate marker) for cardiovascular risk, in humans.[6] Polyphenol-rich foods substances that are known to positively influence FMD include purple grape juice, black tea, bitter-kola, kola nut, *Moringa*, rooibos tea, kinkeliba, bitter leaf, scent leaf, and *Morinda lucida*.

The main physiological activity associated with polyphenols, especially flavonoids, is their remarkable antioxidant properties. Plant extracts that contain high amounts of polyphenols also exhibit high antioxidant activity.[7] Many studies have established a distinct

TABLE 3.1

Examples of Nutraceuticals and Health Foods from Africa and Their Health Benefits

Functional Food	Nutraceutical	Health Benefits
Palm oil (*Elaeis guinense*)	Lycopene	Antiprostate cancer, antioxidant
Carrots, palm oil, tomatoes	β-Carotene	Antioxidant (nonsmokers)
Grape skins, red wine	Resveratrol	Antioxidant, decrease LDL and increase high density lipoproteins (HDL)
Grains, nuts	Selenium	Antioxidant
Banana, leafy green vegetables	Lutein	Improves vision, antioxidant
Citrus fruits, vegetables	Folic acid	Reduces plasma homocysteine
Bitter leaf (*Vernonia amygdalina*)	Vernonia sesquiterpenes	Antidiabetic, lowers cholesterol, prebiotic
Pepper fruit	Capsaicin	Anti-inflammatory
Kola nut	Caffeine, catechins	CNS stimulant, antioxidant
African scent leaf (*Ocimum* species)	Essential oil	Stress reduction, anti-inflammatory, lowers blood sugar
Coconut	Virgin coconut oil	Emollient, antipeptic ulcer, antimicrobial against *Helicobacter pylori*
Alligator pepper	Oleoresin	Anti-inflammatory, antioxidant, mouth odor treatment, painkiller
Rocket (*Eruca vesicaria*)	Isothiocyanates	Anticancer, diuretic, antioxidant, aphrodisiac
Tarragon (*Artemisia dracunculus*)	Remoulade extract	Toothache, dysmenorrhea, digestion
Njangsa (*Ricinodendron heudelotii*)	Oil, γ-tocopherol	Antioxidant, cough, metabolic syndrome
Onions	Allicin	Antimicrobial, cancer chemopreventive
Bitter-kola	Kolaviron	Antiviral, anti-inflammatory, antioxidant
Fruits, leafy vegetables, palm oil	Flavonoids, anthocyanins	Antioxidants, anticholesteric, antiarthritic, anticancer, antiviral
Sorghum (brans)	β-Glucan	Lowers blood lipid, antioxidant
Sorghum (sheaths)	Phyto-erythropoietin K	Antisickle cell anemia, hemoglobin growth
Koseret leaves (*Lippia adoensis*)	Essential oil	Carminative, stomachache, antioxidant
Sumbala (*Parkia bilobosa*)	Fermented seed paste	Antihypertensive, probiotic, aphrodisiac
Ogbono (African bush mango)	Dika fat	Antiobesity
Pigeon pea (*Cajanus cajan*)	Cajanus seed extract	Sickle cell anemia, antioxidant, female hormone mimic

correlation among total phenolic content, total flavonoid content, and antiradical activity in several plant parts.[8–10] Apart from their antioxidant activity, polyphenols have been implicated in the modulation of several diseases such as chronic inflammation, diabetes, cardiovascular diseases, and multidrug-resistant infections.

3.2.1 Flavonoids

What then are flavonoids? Flavonoids (Latin: flavus, "yellow") are secondary polyphenolic metabolites involved in many aspects of plant development, auxin transport, abscisic acid (ABA) biosynthesis, and structural reinforcement. They contribute attractive colors to fruits and flowers that aid in seed and pollen dispersal, and adaptation to environmental conditions such as cold, phosphate starvation, ultraviolet (UV) stresses, pathogen attack, allelopathy, mediation of stigma–pollen interactions, and signaling to mutualist microbes for nitrogen fixation.[11]

3.2.2 Cocoa Polyphenols

Polyphenols found in pigment cells constitute about 10%–18% of the dry weight of unfermented cocoa beans (*Theobroma cacao*). They are a major component of cocoa powder and chocolate derived from processed cocoa beans. Procyanidins comprise up to 60% of the cocoa polyphenols found occurring mainly as homodimers of (–)-epicatechin or heterodimers of (–)-epicatechin and (+)-catechin. Other procyanidins found in cocoa include mixed dimers and oligomers containing various catechin and flavonoid units. Many studies have demonstrated that polyphenols found in cocoa powder and dark chocolate have significant antioxidant effects both *in vitro* and *in vivo*. Its antioxidant properties is responsible for the ability of cocoa polyphenols to reduce the expression of phytohemagglutinin-induced interleukin 2 (IL-2) mRNA, and the expression of interleukin 1 beta (IL1β), in peripheral blood mononuclear cells (PBMC). They also inhibit the oxidation of low density lipoproteins (LDL), which is believed to be a pivotal factor in the pathogenesis of atherosclerosis. These properties are partly responsible for the immense value attributed to cocoa polyphenols as anti-inflammatory and immunomodulatory agents.

Cocoa consumption appears to be beneficial in the management of hypertension among the elderly population. In a study examining blood pressure and peripheral arterial responses to cocoa in 15 young (<50 years old) and 19 older (>50 years old) healthy subjects, flavanol-rich cocoa was found to enhance endothelial function to a greater degree among older than younger healthy subjects.[12] This finding suggest that the blood pressure reducing effects of cocoa are significantly more beneficial to elderly individuals, who are more likely to have vascular pathology. Flavanol-rich cocoa has also been reported to have caused diminished arginase activity in rat kidney, with RBC arginase activity lowered in healthy humans after consumption of a high-flavanol beverage *in vivo*.[13]

3.3 β-Carotene

β-Carotene is a member of a class of polyisoprenoids called carotenoids. β-Carotene is responsible for the color of carrots and is also found in palm oil, banana, amaranth, cantaloupe, broccoli, collard greens, *Calendula*, rose hip, spinach, and several leafy vegetables. Carotenoids are the principal pigments responsible for the red, orange, yellow, and green colors of vegetables. β-Carotene along with α-carotene, lycopene, lutein, β-cryptoxanthin, and zeaxanthin are major dietary supplements used for their antioxidant, immunomodulatory, anticarcinogenic, and antiatherogenic properties. Three of the carotenoids, β-carotene, α-carotene, and β-cryptoxanthin, are called provitamin A carotenoids as they can serve as dietary precursors of vitamin A (all-*trans* retinol). The other carotenoids that are not used by the body in the preparation of vitamin A are referred to as nonprovitamin A carotenoids. Both types of carotenoids are subjects of intense biochemical and clinical investigation to determine their role in human nutrition and health. β-Carotene is placed in the USFDA category of GRAS for use as a dietary supplement and nutrient, as well as a colorant in the food, drug, and cosmetic industries.

Several observational epidemiological studies have shown that an inverse association exists between dietary β-carotene intake and several diseases, including a number of cancers, especially lung and prostate cancers, coronary artery disease, cataracts, and age-related macular degeneration. Studies have also shown that β-carotene has some immunomodulatory effects. The exact mechanism of the compound's antioxidant and

anticancer activities is not clearly understood. The product of its *in vivo* bioconversion, retinol, itself appears to have low antioxidant activity; therefore, it is unlikely that retinol is involved in any significant level in the *in vivo* activity of β-carotene. Whereas there is an overwhelming epidemiological evidence that those who consume three or more servings of fruits and vegetables that are rich in carotenes have significantly lower risks of many forms of cancer and heart diseases, the clinical studies have produced ambiguous reports. The review of the clinical studies on the health benefits of β-carotene has shown that while the compound was found to be beneficial with significantly reduced mortality from gastric and other cancers in marginally nourished subjects in a large study called the Lixian intervention trial, three other large intervention studies in normally nourished subjects, long-term smokers, former smokers, and those exposed to asbestos found no overall benefits from high-dose β-carotene supplementation. In one of these studies, there was a significant 18% excess incidence of lung cancer among those who received β-carotene supplementation. These findings raise serious issues on the exact role of β-carotene in disease prevention and health optimization. Moreover, even in the large Lixian intervention trial, only a combination of β-carotene, vitamin E, and selenium of four dietary regimens tested against placebo had significant protective effects against gastric and esophageal cancers.[14]

The apparent conflicting outcomes could also be due to the complexity of cancers, their prevention, and treatment. It also illustrates the pitfalls of overreliance on clinical trials to answer questions about benefits in disease control. It is imperative that we consider all the available evidence for and against each intervention in order to reach a conclusion that will be beneficial to human health. It has been noted by experts in this area of study that the nature of the subject is such that "there will never be a single, perfect study that will determine once and for all whether these agents prevent heart disease or cancer or any other entity."[15]

3.4 Phytosterols and Phytostanols

Phytosterols occur widely in many African dietary plants. They are structurally related to cholesterol. The latter occurs only in animals and is not found usually in plants. Phytosterols are characterized by the presence of cyclopentano-perhydro-phenantherene ring structure and differ primarily in the nature of the side chain. The phytostanols are different from phytosterols in the absence of a double bond in the sterol structure. Phytosterols and phytostanols are virtually insoluble in aqueous media and are only sparingly soluble in lipids. Esterification with long-chain fatty acids is necessary to enhance lipid solubility. Phytosterols and phytostanols are used in the management of hypercholesterolemia. The mechanism of the anticholesterolemic activity of plant sterols is not properly understood but it is believed that it is due to the inhibition of the absorption of dietary cholesterol and the reabsorption of endogenous cholesterol from the gastrointestinal tract. Individual beneficial phytosterols and the dietary plants that contain them will be discussed in the chapters that follow.

3.4.1 β-Sitosterol

β-Sitosterol is a phytosterol with a close structural relationship to cholesterol. It differs from cholesterol by the presence of an ethyl group at the C-24th position of the side

chain. It is widely distributed in many African dietary plants as esters and glycosides. It is abundant in the three plants currently used in the management of benign prostatic hypertrophy (BPH): pumpkin seeds (*Curcubita pepo*), Prunus (*Pygeum africanum*), and saw palmetto (*Serenoa repens*). Although no clear linkage has been established between the compound and the clinical activity of these herbs, β-sitosterol is used as a medicine in Europe for the management of BPH. It is poorly soluble in lipids and insoluble in aqueous media.

3.4.2 Lupeol

Lupeol is a pentacyclic triterpenoid found in several African medicinal plants, including *Hibiscus sabdariffa*, *Ficus cordata* Thunb (Moraceae), *Albizia adianthifolia* (Fabaceae), *Mimosa invisa* (Mimosaceae), *Irvingia gabonensis Klainedoxa gabonensis* Pierre ex Engl. (Irvingiaceae), *Moringa oleifera*, and *Turraeanthus africanus* (Meliaceae). It has been shown that lupeol possesses cardioprotective properties due to its hypercholesterolemic effect as evidenced by the diminished lipid abnormalities and abnormal biochemical changes induced by cholesterol- and cholic acid-fed rats,[16] as well as the protective effects against benzo-[*a*]-pyrene-induced clastogenic changes in Swiss albino mice. It is also hepatoprotective against CCl_4 and aflatoxin B_1-induced damage in rats. The protective effect of lupeol in ameliorating the renal injury associated with hypercholesterolemia was also reported.[17]

3.5 Catechin

Catechin is a flavonol found occurring naturally in several African medicinal plants. It has been established as a major antioxidant. It was originally obtained from catechu, which is the tannic juice or boiled extract of *Acacia catechu* (Fabaceae). Catechin occurs in its free form or as associated products in *Cola* species, *Psidium guajava*, *Ficus mucuso*, *Ficus gnaphalocarpa*, *Ficus cordata*, *Khaya grandifoliola*, *Holothuria atra*, *Thalassodendron ciliatum*, and also in *Guibourtia coleosperma*, *Terminalia sericea*, *Peltophorum africanum*, and *Acalypha wilkesiana*.

3.6 Epigallocatechin-3-Gallate

Epigallocatechin-3-gallate or epigallocatechin gallate (EGCG) is an ester of epigallocatechin and gallic acid that occurs in tea and it is believed to be responsible for the health benefits associated with tea consumption. It has a remarkable antioxidant property. EGCG is found in many African plants used as dietary supplements, including kinkeliba (*Combretum micrathum*), sorrel (*Rumex abyssinicus*), Egyptian rumex (*Rumex vesicarius*), rooibos tea (*Aspalathus linearis*), and white milkwood (*Sideroxylon inerme*). EGCG from green tea has been shown to be beneficial for the prevention and treatment of many diseases, including various cancers, autoimmune and inflammatory diseases, and CNS and immune-deficiency disorders. It has also shown promise as an effective antiviral agent with significant activities against HIV and herpes simplex virus (HSV).[18]

3.7 Resveratrol

Resveratrol, 3,4′,5-trihydroxystilbene and 3,4′,5-stilbenetriol, is a naturally occurring phytoalexin found in grapevine and other plants. Phytoalexins are defensive chemicals produced by plants in response to injury or against infection by pathogenic microorganisms. Resveratrol exists in both the *cis* and *trans* stereoisomeric forms. It can be extracted from grape skins by simple solvent maceration, along with other grape phenolics, including quercetin, procyanidins, prodelphidins, catechins, and gallocatechins. The compound is also found in wine, with greater quantities found in red wines than in white ones. Resveratrol has strong antioxidant properties and has shown significant cardioprotective and antiproliferative activities in several studies. Resveratrol and other polyphenols found in red wine are believed to be largely responsible for the so-called French paradox, a term that is used to describe the observed lower rate of coronary heart disease mortality in France when compared to the rate in other industrialized countries with similar risk factor profile. Apart from grapes and wine, resveratrol occurs in peanuts, eru (*Gnetum africanum*), and *Erythrophleum lasianthum*. Related stilbenes have been isolated from several African medicinal plants.[19]

3.8 Proanthocyanidins

Proanthocyanidins (condensed tannins) are a major group of phenolic compounds that occur widely in fruits, vegetables, nuts, seeds, flowers, and bark. Structurally, they are a class of compounds that take the form of oligomers or polymers of polyhydroxy flavan-3-ol units, such as (+)-catechin and (–)-epicatechin. They are considered important nutraceuticals because of their pronounced antioxidant and anticancer properties, as well as their protective role against several viral, bacterial, and parasitic infections, and against cardiovascular diseases. Proanthocyanidins exert their biological activities via at least three general mechanisms: (a) transition metal ion complexation, (b) as antioxidants, and (c) by complexation with biomolecules such as peptides, proteins, and polysaccharides. The proanthocyanidins comprise flavan-3-ol di- through oligo- to polymers that produce anthocyanidins by cleavage of a $C(sp^3)$–$C(sp^2)$ interflavanyl bond under acid catalysis. This classification is now considered arbitrary with the reported characterization of several dimeric promelacacinidins/proteracacinidins with (sp^3)–O–$C(sp^3)$ interflavanyl bonds and some trimeric analogs containing both $C(sp^3)$–$C(sp^2)$ and $C(sp^3)$–O–$C(sp^3)$ interflavanyl bonds. The monomeric units (flavonoids) are referred to as leucoanthocyanidins; these are flavan-3,4-diols and flavan-4-ols, that produce anthocyanidins by cleavage of a $C(sp^3)$–O bond on heating with mineral acid. The proanthocyanidins and the bi- through hexa-flavonoids constitute the two major classes of complex C6–C3–C6 secondary metabolites. Anthocyanins are anthocyanidins with sugar moieties attached to them. It is believed that these compounds rarely exist in nature as aglycones (i.e., without sugars and/or other plant metabolites). There are 32 naturally occurring monomeric anthocyanidins that have been properly identified and characterized; most of the identified anthocyanins are based on cyanidin (31%), delphinidin (22%), and pelargonidin (18%), which only differ by the hydroxylation pattern of their B-rings. The other three common anthocyanidins (peonidin, malvidin, and petunidin), which contain methoxyl

group(s) on their B-rings, constitute together the aglycones of 21% of the reported anthocyanins.[20]

Certain beans and pulses have been shown to contain natural cyanidins, peonidin, and pelargonidin in extracts based on a careful extraction process and purification followed by liquid chromatography–mass spectrometry (LC–MS) for identification purposes.[21] The better known occurrence of only anthocyanidins in their nonglycosidated forms in plants are the 3-deoxyanthocyanidins found in *Sorghum bicolor*, spagnorubins in peat moss (*Sphagnum* spp.), and rosacyanins from petals of *Rosa hybrida.*

Some of the most important dietary proanthocyanidins are those obtained from grape fruit, kola nuts (*Cola acuminata*), cocoa, coffee, *Sorghum*, banana, berries, avocado, mangoes, tomatoes, cabbage, lentils, eggplant, garden-eggs, bitter leaf (*Vernonia amygdalina*), bissap (*Hibiscus sabdariffa*), many spices and herbs, and leafy green vegetables. As indicated above, there is an enormous variety in the structural characteristics of the proanthocyanidins, anthocyanins, and the constituent flavonoids such that that there is a high degree of specificity of biological activities associated with each source.

3.9 Tocotrienols

Tocotrienols are closely related to tocopherols and together they form part of the vitamin E structural class. The tocotrienols differ from the tocopherols in the nature of the side chain or tail; whereas the tocopherols have a saturated phytyl side chain, the tocotrienols have an unsaturated isoprenoid or farnesyl side chain with three double bonds. There are four tocotrienols: α-, β-, γ-, and δ-tocotrienols, which follow the nomenclature of the tocopherols. Tocotrienols are lipid soluble and have strong antioxidant and anti-inflammatory activity. They are valued for their beneficial effects on human health for their anticarcinogenic, hypocholesterolemic, antiatherogenic, immunomodulatory, and antithrombotic properties.

Tocotrienols have shown promise as a potential agent for the prevention and therapy of AD. It has been suggested that tocotrienol-containing plant foods and tocotrienol derivatives and formulations with enhanced bioavailability may offer a novel approach in AD prevention and treatment.[22] It was found that tocotrienols, but not tocopherols, block the processing and nuclear localization of sterol regulatory element binding protein-2, the transcriptional factor for HMG CoA reductase (3-hydroxy-3-methyl-glutaryl-coenzyme A reductase) and farnesyl pyrophosphate (FPP) synthase, and enhance the degradation of HMG CoA reductase. Consequently, tocotrienols deplete the pool of FPP and geranylgeranyl-pyrophosphate (GGPP) and potentially blunt prenylation-dependent AD pathogenesis. The anti-inflammatory activity of tocotrienols further contributes to their protection against AD. The mevalonate- and inflammation-suppressive activities of tocotrienols may represent those of an estimated 23,000 mevalonate-derived plant secondary metabolites called isoprenoids, many of which are neuroprotective. The compounds also have possible roles in the prevention and treatment of various cancers, bone resorption, diabetes, and cardiovascular and neurological diseases.[23]

Tocotrienols are abundant in palm oil (*Elaise guineense*), palm kernel oil, rice bran oil, the nonpolar fraction of *Garcinia kola* extract, and coconut oil. They also occur in rather limited amount in other vegetable oils, cereal grains, and certain leafy vegetables.

3.10 Ubiquinone

Ubiquinone (coenzyme Q_{10}, CoQ_{10}) is a redox component of transmembrane electron transport in mitochondria. The basic structure of ubiquinone consists of a benzoquinone "head" and a terpenoid "tail." It is the benzoquinone component that participates in the redox activity of the electron transport chain. Coenzymes Q occur in the majority of aerobic organisms from bacteria to plants and animals.

3.11 Essential Oils

These are volatile plant constituents usually obtained from steam distillation or by mechanical processes, or by solvent extraction of certain plants. They are called "essential oils" because they were originally valued for their fragrances, "essences." They are also known as "volatile oils" although they have boiling points well above 100°C. Essential oils are important items of commerce, being used for their organoleptic properties as perfumes, food flavorings, and personal care products. They also have immense medical value as antioxidants and carminatives and are a major component in the medicines of the therapeutic system known as aromatherapy.

Essential oils elaborate a complex mixture of compounds, which can be classified into two major groups: the terpenoids and phenylpropanoids. The most common compounds found in essential oils are however simple hydrocarbons, alcohols, aldehydes, ketones, phenols, oxides, and esters. The physical characteristics and biological activity of any essential oil is dependent on the type of compounds present and their relative quantities. Since well over 100 of such compounds can be present in any particular essential oil, there is enormous variability in the composition of essential oils, even among oils obtained from the same species. Apart from their use in aromatherapy, essentials in dietary plants have been associated with antimicrobial (including antibacterial, antiviral, and antifungal), sedative, diuretic, antitussive, and spasmolytic actions. Essential oils can also be classified according to their functional groups of major components. These functional groups play a large part in determining the pharmacology and toxicology of the essential oil component; for example, ketones are more active and toxic than alcohols, and alcohols and phenols are more potent as antimicrobial agents, with phenols being more irritant. It has also been observed that essential oil components often exhibit optical isomerism (where the two isomers are mirror images of each other.)

The quality of the oil produced is largely dependent on the source of the plant and the method of production. Essential oils occur mainly in higher plants and the plant genera that are capable of producing the essential oil component are distributed in about 50 families, belonging to the Asterales, Magnoliales, Lamiales, Laurales, and Rutales orders. Members of the Violales contain the fragrance principle but do not produce mono- or sesquiterpenes.[24] Essential oils occur in all types of vegetable organs: flowers (rose and bergamot tree), leaves (scent leaves and lemongrass), bark (cinnamon), woods (sandalwood), rhizomes (ginger and turmeric), roots (vetiver), fruits (anise), and seeds (alligator pepper and grains of paradise). In commerce, the oils obtained from different parts of the same plant are treated as distinct articles of trade since they may not be used for similar purposes.

3.12 Glucosinolates and Isothiocyanates

Glucosinolates and isothiocyanates are related to essential oils because of their pungent properties, although they are not chemically similar. They are sulfur- and nitrogen-containing glycosides responsible for the pungent properties of horseradish and mustard. Glucosinolate itself is not pungent but when it encounters the enzyme myrosinase, normally stored in another compartment of the cell, the aglycone is formed, which then usually rearranges into a pungent and corrosive isothiocyanate. Glucosinolates can also yield isothiocyanates by steam distillation during the production of the so-called mustard oils.

3.13 5-Hydroxy-L-Tryptophan

5-Hydroxy-L-tryptophan (5-HTP) is a major component of the West African herb, *Griffonia simplicifolia*. It is isolatable from the seeds and the leaves. 5-HTP is a precursor of the neurotransmitter serotonin, which in the CNS has been found to regulate sleep, appetite, body temperature, and sexual behavior and to have a role in depression, anxiety, aggression, and pain sensation. Serotonin itself is an indole derivative that is synthesized from the essential amino acid L-tryptophan (LT). 5-HTP is not commonly found in large quantities in food. The amino acid tryptophan, from which the body makes 5-HTP, occurs naturally and is found in potatoes, pumpkin, sunflower seeds, and turnip and collard greens.

3.14 Dietary Fiber

The health potential of dietary fiber is fairly well known following the work of the British doctor Dennis Burkett in East Africa with a primary focus on the effect of fiber consumption on gastrointestinal function (constipation, appendicitis, diverticular disease, colorectal cancer [CRC], cardiovascular diseases, etc.), reduction in blood cholesterol, and modulation of blood glucose. Subsequent work by others has established that foods with high quantities of dietary fiber can reduce the risk of cardio-vascular disease (CVD), type 2 diabetes, and various cancers. Because of the difficulty in conducting clinical trials on a substance that is largely unabsorbed in the gastro-intestinal tract (GIT), the validation of the health effects of dietary fiber has been inconsistent. Dietary fiber as nutraceuticals has been widely accepted for its beneficial physiological effects such as improved intestinal function, cholesterol reduction, regulation of glucose and insulin responses, and increased microbial biomass and improved microbiota composition due to the fermentation of dietary fiber in the large colon, which also produces short-chain fatty acids. Fibers in human diets come from the cell walls of fruits, vegetables, cereal grains, and oil seeds. It includes polysaccharides (the degree of polymerization is denoted as DP; the number of glucose residues per chain), oligosaccharides (DP > 2), and lignins. The European Prospective Investigation into Cancer and Nutrition (EPIC) showed a strong dose-dependent reduction in CRC risk with greater fiber consumption. Other large prospective cohort studies have also shown the correlation between dietary fiber and health. Although these

studies have provided valuable insights into the relationships among dietary intake, lifestyle factors, and disease risk, they are somewhat limited by the time taken from study initiation to the emergence of the clinical end points (including death and nonfatal events). The elapsed time can be years so that there may well be substantial changes in key study factors—of great relevance for foods where there is a strong possibility of compositional variation with time.[25]

Dietary fibers are characterized as "soluble dietary fibers" and "insoluble dietary fibers." The insoluble fibers do not dissolve in hot water, and they consist mainly of cellulose, hemicellulose, lignin, and other components that are intimately associated with nonstarch polysaccharides. Whole-grain cereals and whole meal bread are particularly good sources of insoluble fiber. In the laboratory, the quantitative determination of insoluble fibers is carried out using the methods described by AOACI 2002.02 in which the samples are digested and the subsequent isolation and gravimetric measurement are as contained in the procedures outlined in AOAC 985.29 and 991.43. Soluble fibers are those that can be dissolved in hot water; they can be further divided into high-molecular-weight soluble dietary fibers (HMWSDF) and low-molecular-weight soluble dietary fibers (LMWSDF). The determination of LMWSDF can be carried out by LC, whereas quantitative determination of HMWSDF content in foods is determined by alcohol precipitation followed by gravimetry.[26] The major types of dietary fiber include the following.

3.14.1 Cellulose

Cellulose is the most abundant plant polysaccharide, accounting for 15%–30% of the dry mass of all primary cell walls. Cellulose is an insoluble dietary fiber, which consists of a linear polymer of D-glucose with β-1,4-linked pyranosidic residues and has a variable degree of polymerization depending on its origin. The DP can range from 1000 to 14,000 (with corresponding molecular weights [MWs] of 162–2268 kDa). Hydrogen bonding between sugar residues in adjacent chains imparts a crystalline microfibril structure, which does not dissolve in hot water. It is found in vegetables, fruits, cereals, and legumes; it coexists with hemicelluloses, pectin, and lignin. The structure and functional properties of cellulose depend largely on the plant source.[27] Major sources of dietary cellulose in African cuisine include okra, *Gnetum*, bitter leaf, elephant grass, and assorted leafy vegetables.

3.14.2 Hemicellulose

Hemicelluloses are polysaccharides that occupy the spaces between cellulose fibrils within the cell walls of plants and sometimes form the plant cell wall matrix with pectin. Hemicelluloses, such as arabinoxylans and arabinogalactans, are obtained from pulses and cereals. They exhibit specific characteristics depending on the source and the associated compounds. Arabinoxylans, also known as pentosans, have a β-1,4-linked xylan backbone with side chains composed of furanosidic arabinose residues. The arabinoxylans derived from the endospermic cell walls of wheat and other cereals are water soluble but the arabinoxylans in the outer layers of the grain (e.g., wheat bran) are not soluble due to covalent cross-links by ferulic acid with lignins and proteins.

3.14.3 Lignin

Lignin is found co-occurring with cellulose and other components of insoluble dietary fiber; however, it is not a carbohydrate but a highly cross-linked, complex three-dimensional

structure based on phenylpropane units. Lignin is the second most abundant natural raw material and nature's most abundant aromatic (phenolic) polymer. It is interesting that lignins are classified as dietary fibers only by association with dietary fiber polysaccharides, especially their covalent linkage to hemicellulose. When it is extracted or isolated from the plant cell wall, it is not regarded as a dietary fiber but a polyphenolic substance. Lignin is important for the digestibility and probably also for the physiological properties of dietary fiber in man; and lignin may play an important role as a binder of bile salts in the human gastrointestinal tract.[28]

3.14.4 Pectin

Pectin is regarded as a soluble fiber, obtained commercially as a purified carbohydrate product from the dilute acid extract of the inner portion of the rind of citrus fruits or African bush mango, or from apple pomace. It is a natural hydrophilic colloid, in a linear polysaccharide chain containing from 300 to 1000 monosaccharide units. It consists chiefly of three structural elements: a homogalacturonan, galacturonan with side chains, and a rhamnogalacturonan consisting of the disaccharide units [→ 4)-α-D-GalA-(1 → 2)-α-L-Rha-(1 →] as backbone and with highly branched arabinogalactan chains. The galacturonic acid residues are either free (pectic acid) or present as methyl esters (pectin). Free uronic acid residues are ionized at physiological pH and they may bind minerals, especially calcium and magnesium, in the intestinal tract and interfere with their absorption.[29] Pectin is important in the food industry as a thickener, emulsifier, and gelling agent.

3.14.5 β-Glucans

β-Glucans are polysaccharides that occur in the subaleurone and endosperm cell walls of the seeds of cereals. They are typical linear homopolysaccharides, which have only a single β-D-glucopyranose (β-D-Glcp). Over 90% of the β-D-Glcp residues in β-glucans are arranged as blocks of two or three consecutive (1/4)-linked units separated by a single (1/3)-linkage, which form the two building blocks of cereal β-glucans: a cellotriosyl unit and a cellotetraosyl unit. The remaining less than 10% of the polymer chain is mainly composed of longer cellulosic sequences ranging from 5 to 14 β-D-Glcp residues. The functional properties of β-glucans in aqueous solutions are time dependent; the polysaccharide chains tend to form aggregates with time and could essentially form gel under favorable conditions. These functional properties are affected by structural features, such as trisaccharide-to-tetrasaccharide ratio, their linkage pattern, and their molecular weight, as well as by temperature and concentration.[30] β-Glucans can be incorporated into various products, such as bread, muffins, pasta, noodles, salad dressings, beverages, soups, and reduced-fat dairy and meat products. The benefits of ingestion of β-glucans include lowering of blood serum cholesterol, regulation of blood glucose levels, which may be of value for those with diabetes, and reduction in the risk of developing CVD. These health benefits are also correlated with the amount and molecular weight of the solubilized β-glucans in the gastrointestinal tract.

3.14.6 Mucilages and Gums

Mucilages and gums are less well-defined polysaccharide derivatives. Mucilages are considered as normal plant constituents, whereas gums are regarded as pathological products arising from injury to the plants or cell wall decomposition. They are known to contain

both pentose and hexose residues, as well as their oxidant products, uronic acid units. The carboxyl groups are usually neutralized by calcium or magnesium ions.[31] Although it is technically possible to distinguish mucilages from gums, such differentiation however does not serve any useful purpose in their use as nutraceuticals. Mucilages do not actually dissolve in water but only swell to form a viscous mass, whereas gums on the other hand, are normally fairly soluble in water.

Mucilages are slimy colloids of water-soluble macromolecular polysaccharides that occur naturally in special mucilage cells that form the outer layer of seeds of the plantain family and other species. They are water-soluble fibers that are often characterized by their high water-holding capacity (WHC). Three mucilages are considered official because they have been detailed in several pharmacopeias; they include psyllium gum, yellow mustard mucilage, and flaxseed gum. The structure of psyllium gum is highly branched, mainly consisting of a neutral arabinoxylan with (1 → 4) and (1 → 3) xylopyranose backbones; the side chains are composed of arabinose and xylose, which are connected to the main chain by O-3 and/or O-2 linkages. Psyllium gum is an effective laxative agent and it can promote the health and function of the colon.

Yellow mustard mucilage is extracted from the seed coat of yellow mustard (*Sinapis alba*). It is composed of neutral and acidic polysaccharides consisting of glucose, arabinose, xylose, rhamnose, galactose, and mannose. It exhibits unique rheological properties and significant synergistic interactions with four types of galactomannans, namely, locust bean gum, guar gum, tara gum, and fenugreek gum. Yellow mustard mucilage is an excellent emulsion stabilizer. Flaxseed gum is extracted from the hulls of flaxseed (*Linum usitatissimum*). It can be fractionated into a neutral and an acidic fraction. The neutral fraction is mainly composed of a high-molecular-weight arabinoxylan, whereas the acidic fraction is mainly composed of a pectin-like rhamnogalacturonan.

Gums are natural plant hydrocolloids, comprising translucent, amorphous substances that are frequently produced in higher plants as a protection after injury. Gums are typically heterogeneous in composition. Upon hydrolysis, arabinose, galactose, glucose, mannose, xylose, and various uronic acids are the most frequently observed components.[32] Polysaccharide-based hydrocolloids can also be grouped in this class of dietary fiber because although they are water soluble they cannot be digested by human enzymes. This group includes naturally exuded gums (gum arabic, ghatti, karaya, and tragacanth), seed gums (galactomannans: locust bean gum, guar gum, tara gum, and fenugreek gum), fermented gums (xanthan gum and gellan gum), and seaweed gums (alginates, carrageenans, and agar).[33]

3.14.7 Oligosaccharides

Oligosaccharides are characterized by their lower number of sugar units. They occur in many dietary plant species but like most polysaccharides they cannot be digested by humans. Inulin (MW 5000–6000 Da) is a typical oligosaccharide that is soluble in warm water and which occurs as a reserve carbohydrate in many African plant families. Inulin contains about 30 furanoid D-fructose units in a β-1,2-linkage. It is largely nondigestible in the small intestine, but it is easily degraded by the bacteria in the large intestine to short-chain fatty acids. It is used commercially in many food products, such as biscuits, yogurt, desserts, and sweets as a sugar and fat substitute.[29]

One of the most important health management issues facing African countries is that the risk of nutrient imbalance is highest in vulnerable populations that are unable to access essential or conditionally essential nutrients. These are usually the very young and the

frail elderly. The lack of adequate nutrition may be due to seasonal and unexpected losses of agricultural produce but inadequate nutrition–health education seems to be a major causative factor. Poverty and growing economic disparities may be another major factor; however, both rich and poor alike are affected by the nutritional deficiencies that are essentially due to the transitional status of modern African societies.

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4

Modern Trends in the Use of Functional Food Plants of Africa

4.1 Introduction

Functional foods still remain a boundary concept in Africa, and their use, processing, manufacture, and marketing combine elements of food technology and those of the modern pharmaceutical industry. The absence of a clearly defined regulatory framework for this category in most African countries dictates that individual products are considered according to the "intended use" as designated by the manufacturer. For example, if tomato is presented as a fruit, it will be produced and regulated as such with all the applicable rules to ensure the safety of consumers. On the other hand, if tomato extract or isolated lycopene is packaged as a dietary supplement without any therapeutic claims, it will pass through most regulatory regimes as a "dietary supplement" and yet the same product will be considered a phytomedicine, which is a form of a drug if there are specific indications of its use in the management of prostate gland enlargement. When tomatoes are added as an ingredient in remedies used in traditional medicine, the resultant product is treated as a traditional medicinal formulation and the appropriate method of processing and regulation apply. Another widely used term is "fortified food" to describe the intentional addition of certain micronutrient or phytochemical, either to enrich the nutritional profile of a food substance or to enhance its health-promoting ability. Using tomatoes as an illustration, the tomato could be made to contain lycopene that is in excess of its natural composition as a "fortified food." In this regard, a functional food could be considered a vehicle for the delivery of nutraceuticals and other phytochemicals to the body.

Following the worldwide interest in healthy living and the demonstrable link between phytonutrient intake and the prevention of certain diseases, functional foods have become an important subject of great interest to nutritionists, physicians, and pharmacognosists. Both the food and pharmaceutical industries have continued to develop new products to which ingredients have been added to confer functionality on the dietary substance beyond its normal food value. There is also the concerted promotion of certain dietary ingredients by the food industry as being ergogenic, or capable of increasing physical performance, or being of ethnic origin, and some other manufactured foods as improved modifications of natural food substances. The undiscerning public is often caught in the web of one healthy-living fad or another. Some of the biggest victims include those looking for "drugless" weight loss or antiobesity products, and people looking for "natural super foods" that will enhance their physical fitness and restore their health, and the attraction of wholesome "natural" products that promote vitality and slow down aging and age-related diseases.

Most of the functional foods available in the market are not derived directly from processed natural dietary plants in which the beneficial attributes are enhanced through physical manipulation of the food substance. They are rather products of innovation by food companies and the pharmaceutical industry. Functional foods have been developed in virtually all food categories. The major categories of manufactured functional foods include the following: enriched products, enhanced commodities, altered products, and fortified foods.

Enriched products: These are manufactured foods with new nutrients or components added that are not normally found in a particular food. Typical example is the margarine with plant sterol ester, probiotics, prebiotics, and even with added vitamin D.

Enhanced commodities: Food in which one of the components has been naturally enhanced through special growing conditions, new feed composition, genetic manipulation, or otherwise. Examples include a tomato that has been bred to produce larger quantities of lycopene beyond the normal natural composition.

Altered products: This defines food from which a deleterious component has been removed, reduced, or replaced with another substance with beneficial effects. Examples include cassava that is devoid of cyanoglycosides and dietary fibers developed as fat releasers in meat or ice cream products.

Fortified product: Food with additional nutrients, for example, flour and bread with added vitamin A, fruit juices fortified with vitamin C, and breakfast cereals with additional vitamins.

Regardless of the type or nature of the physical manipulation to enhance the functionality of African dietary plants, most of the modifications are derived directly from indigenous food processing methods. Sophistication is introduced by the application of modern technology. Three product types will be elaborated in this section: (i) the biopharming of some African functional foods for the production of drugs and related therapeutic agents, (ii) the modifications of some functional foods for improved bioavailability, and (iii) fermentation products.

Africa as the cradle of human adaption to the environment has a well-established history of successful exploitation of the continent's immense biodiversity for both food and medicine. The rich traditional medicine has led to the development of many modern food types, drugs, and phytomedicines. However, many of the traditional food products and medicines have been abandoned for the easier-to-process foreign products and synthetic drugs. However, there has recently been a major resurgence in interest in African flora as natural remedies, processed phytomedicines, and sources of pharmacologically active compounds used as starting materials for the development of active pharmaceutical ingredients. A number of international and local initiatives are actively exploring the continent's botanical resources, with an emphasis on working with traditional healers to exploit known medicinal plants, as well as screening unique African plants for chemical leads. A significant number of novel chemical entities are in various stages of development as drugs, some are in clinical trial, and a few are in the market already.[1]

A major problem with the use of functional foods is the development of an appropriate vehicle or medium to deliver the active molecule or desirable phytochemical to the target site and in adequate amount. The effectiveness of nutraceutical products in preventing diseases depends on preserving the bioavailability of the active ingredients. This represents a

formidable challenge, given that only a small proportion of these remain bioavailable following oral administration, because of insufficient gastric residence time, low permeability and/or low solubility within the gut, as well as instability under conditions encountered during normal food processing (temperature, oxygen, light) or in the gut (pH, enzymes, presence of other nutrients), all of which limit the activity and potential health benefits of nutraceutical molecules. The delivery of these molecules will therefore require food formulators and manufacturers to develop food-grade products that both maintain the active molecular form until the time of consumption, and deliver this form to the physiological target within the organism.[2]

Furthermore, most African food plants are traditionally used in their fresh form, almost immediately after harvesting to achieve the desired effects. Storage, even for a few days, often alters the biochemical integrity of the substance. Modern formulations, therefore, must also seek to preserve farm products in as much of their natural state as possible. However, as will be shown later, traditional systems also allow for a deliberate bioconversion through fermentation and related methods to modify the original substance to a more desirable functional food.

The key product delivery systems and major concepts are outlined below.

4.2 Polyherbal Formulations as Bioenhancers

One of the most perplexing encounters with traditional healers during field ethnobotanical surveys is the use of multiple herbs in a single formulation and the insistence by the healers that the "herbs must go together" even when it was almost certain that the sought-after bioactivity could be attributed to only one or two major plants in a plethora of plants used in the recipe. Sometimes the same plants, such as alligator pepper, cayenne, and black pepper, are used as ingredients in several remedies. It is now obvious that such plants are added in the recipe not only for their probable biological activity but as bioenhancers or natural bioactivity modulators to mediate the desired response from the herbs or functional foods. The concept of bioenhancers was first documented by Bose (1929) who described the action of long pepper on *Adhatoda vasika* leaves increased the antiasthmatic properties of *Adhatoda vasika* leaves.[3] Several spices, vegetable oils, and nuts are deliberately added to functional foods to amplify their functionality by increasing their absorption, transportation, and metabolism in the body.

4.3 Use of Nanoparticles to Enhance Bioavailability

Nanoparticles have shown great promise in drug design by altering the bioavailability, pharmacokinetic, and pharmacodynamic properties of natural products molecules to improve therapeutic delivery. Their size, shape, charge, material, coating, and cargo determine their individual functionalities. A systems approach could help predict the behavior of a plethora of nanoparticles interacting in complex biosystems. Developing these nanosystems may lead to biomimetic strategies where interactions between nanoparticles and their environment give rise to cooperative behaviors typically seen in natural

self-organized systems like the human body. Polymeric nanomedicine in a sense is a reverse engineering of the natural environment where these active molecules exist as part of a complex matrix before they were isolated for drug development. Such biomimetic systems can also reduce incidences of protein coronas in which active compounds are sometimes trapped and inactivated.

The most widely used techniques for the preparation of protein nanoparticles include estrusion (gelatin, whey), emulsification–stabilization (soy glycinin, casein, whey protein), spray-drying (silk protein, insulin, gelatin), and coacervation (β-lactoglobulin/gum arabic, albumin/gum arabic, zein, gelatin/gum arabic, xanthan).

4.4 Biopharming

The remarkable development of genetics, molecular biology, and plant biotechnology in Africa in the last two decades has opened the door for the establishment of modern genetic engineering and biochemical technology platforms for plant expression technologies on the continent. This development represents an opportune technology to produce therapeutic agents, including pharmaceuticals and vaccines using plants as biofactories. This involves the use of plants for the stable or transient expression of pharmaceutically important compounds, largely protein-based biologics and vaccines. Though this class of product is not traditionally classified as functional foods they are of interest if the plants are not used simply for the extraction and isolation of active pharmaceutical molecules. The application of the tools of modern plant biotechnology has now made it possible for biopharmaceuticals to be produced in plants. It is widely accepted that plant-made pharmaceuticals (PMPs), or molecular pharming, will help to meet the rising demand for biopharmaceuticals, as well as provide a platform for the design of functional foods from native African food crops. Plants can now be considered alongside traditional production platforms and may provide numerous potential advantages over microbial and mammalian production systems.[4]

Most African countries cannot afford disease control through the manufacture of chemically derived pharmaceuticals or cost-intensive vaccines. Alternatively, efforts are being made to produce drugs from plants or edible vaccines, which are cheap and have many advantages over commercialized vaccines. Transgenic plants generated for this purpose are capable of expressing recombinant proteins, including viral and bacterial antigens and antibodies. Common food plants such as banana, tomato, lettuce, tobacco, rice, carrot, potatoes, etc. have been used to produce vaccines against certain diseases such as hepatitis B, cholera, HIV, etc. Thus, the up- and down-regulation of desired genes that are used for the modification of plants have a marked role in the improvement of genetic crops. The use of genetic engineering in generating transgenic lines/cultivars of different crops with improved nutrient quality, biofuel production, enhanced production of vaccines and antibodies is still an emotive subject.[5] Several health-safety and ethical concerns have been raised, but in this section, we are interested only in genetic improvements specifically targeted on the production of foods with improved functionality to target specific health needs.

Some examples of biopharming include the production of functional foods and plants such as tomatoes with incredible quantities of the important nutrients such as lycopene, β-carotene, and vitamin C. Another example is the development of food crops with enhanced ability to elaborate vitamin A. Some of the stable rice transgenic lines accumulate high amounts of provitamin A, giving the endosperm a yellow color, hence the name

golden rice. It has been suggested that people who consume 75 g of golden rice per day automatically have sufficient dietary amount of provitamin A. Similar nutrient value has been reported with specially bred cassava and potato cultivars.

Others are the transformation via recombinant *Agrobacterium tumefaciens*, regeneration and cultivation of transgenic *Nicotiana* spp., biolistic transformation and regeneration of maize, transient expression via small- and large-scale (syringe or vacuum) infiltration of *Nicotiana* plants with *A. tumefaciens*, insect cell culture, and the use of recombinant baculoviruses for protein expression and of a variety of protein concentration and purification techniques and immunoassays for proving expression.

4.5 African Fermented Foods

Fermentation is a very important low-cost food processing technique and historically was a common means of preservation in lesser-developed tropical countries where preservation techniques and packaging are prohibitively expensive. The African continent has one of the richest varieties of lactic acid–fermented foods and an age-old history of producing traditional fermented foods, so no discussion of functional foods would be complete without a review of the contribution of this technique to the production of health foods. Such food types have significantly impacted the nutrition, health, and socioeconomics of the people of the continent, often plagued by war, drought, famine, and disease. Fermented foods can be described as food substrates that are invaded or overgrown by edible microorganisms whose enzymes, particularly amylases, proteases, and lipases, hydrolyze the polysaccharides, proteins, and lipids to nontoxic products with flavors, aromas, and textures that are pleasant and attractive to the human consumer. Fermentation can be undertaken to transform the food substance to more desirable, bioavailable, and less toxic functional foods.[6] Given the lack of adequate storage and mechanical preservation of foods (such as refrigeration, canning, or modified atmosphere) and the generally hot and humid environment, the controlled fermentation of food becomes a more sustainable form. However, if the products of enzyme activities are uncontrolled and the resultant products have unpleasant odors or undesirable unattractive flavors, or the products are toxic or disease producing, the foods are described as spoiled. The difference between "fermented" and "spoilt foods" lies entirely on the desirability and safety of the end product, which is dictated by the nature of the biological culture used for the fermentation, the fermentation environment and process duration, and the absence of contaminants.

Steinkraus has suggested that traditional fermentation of foods serves several functions, including[7]

1. Enrichment of the diet through the development of a diversity of flavors, aromas, and textures in food substrates
2. Preservation of substantial amounts of food through lactic acid, alcoholic, acetic acid, and alkaline fermentations
3. Enrichment of food substrates biologically with protein, essential amino acids, essential fatty acids, and vitamins
4. Detoxification during food fermentation processing
5. A decrease in the overall cooking times and fuel requirements

There is no general agreement on the classification method for fermented foods. Some of the methods used for the classification of fermented foods include (1) the type of organisms by category, for example, yeast fermentation for alcoholic beverages, *Acetobacter* for the production of vinegar, lactobacilli fermentation for pickles and milks, and plant proteins fermented with molds with or without lactobacilli and yeasts; (2) by classes/substrate type, for example, beverages, cereal products, dairy products, fish products, fruit and vegetable products, legumes, and meat products; (3) by commodity/specific substrate, for example, fermented starch roots, condiments, cassava based, cereal, legumes, beverages, etc.; and (4) biochemical parameters such as (a) fermentation producing textured vegetable protein meat substitutes from legume/cereal mixtures, for example, Indonesian tempe and ontjom, (b) lactic acid fermentations, for example, Ethiopian injera, Sudanese kisra, sauerkraut, Korean kimchi, cucumber and other vegetable pickles, live lactic acid–fermented milks, yogurts, Russian kefir, and cheeses; yogurt/wheat mixtures: Egyptian kishk and Greek trahanas; boiled rice/raw shrimp/raw fish mixtures: Philippine balao balao, burong dalag; sour-dough bread; Indian idli; and Philippine puto, (c) acetic acid fermentations including apple cider and wine vinegars in the West, palm wine vinegars in West and Central Africa and the Far East, coconut water vinegar in the Philippines, tea fungus/kombucha in Europe, Manchuria, Indonesia, Japan, and recently in the United States, and Philippine *nata de pine* and *nata de coca*; (d) alkaline fermentations, for example, Nigerian dawa-dawa, Côte D'Ivoire's *soumbara*, African *iru*, *ogiri*, Indian kinema, Japanese natto, and Thai thua-nao, and (e) alcoholic fermentations, for example, grape wines, African burukutu, pito, tombo, Mexican pulque, honey wines, South American Indian chicha and beers, palm and jackfruit wines in India, sugarcane wines, Japanese sake, Indonesian tape, Chinese lao-chao and Thai rice wine, etc.[8] We have deliberately omitted from this classification fermented foods that are grouped according to their functional roles, such as the Sudanese food categorization: (a) kissar (staples—porridges and breads such as aceda and kissra), (b) milhat (sauces and relishes for the staples), (c) marayiss (alcoholic beverages, including various types of opaque beer, clear beer, date wines, and meads), and (d) akil-munasabat (food for special occasions).[9]

Animal protein fermentations, especially milk fermentations, are common throughout the continent, and among the nomadic tribes it is integrated into the societal culture, comprising an important part of the daily diet. Sometimes, special grains and herbs are added to the fermented product for specific functional roles. Examples include *kule naoto*, the traditional Maasai fermented milk product derived from unpasteurized whole milk from Zebu cows in the rural areas, with spontaneous fermentation in a calabash occurring over at least 5 days. *Kule naoto* is an important part of the daily diet of the Maasai community in Kenya and Tanzania. In other regions, *amasi*, a traditional fermented milk consumed in South Africa and Zimbabwe, is prepared by fermentation of raw milk for several days in calabashes made of gourd, or in stone jars; Ethiopian products include *ergo* (fermented sour milk), *ititu* (fermented milk curd), *kibe* (traditional butter), *neterkibe* (kibe or traditional ghee), ayib (cottage cheese), and *arera* (sour defatted milk); and several varieties of *fura nunu* are produced by the pastoral Fulani of West Africa. Additionally, several traditional recipes exist for the production of exotic yogurts in most parts of Africa. Relatively little is known about the microbiology and the presumed dominating lactic acid bacteria (LAB) of these fermentations. The modern modification of the traditional recipes to include various nutrients and vegetables suggests that lactic acid fermentation represents a simple and valuable biotechnology to exploit the health-promoting properties of indigenous African fruits and vegetables.

A classification based mainly on the substrate/food types is used to group the products into four groups for ease of discussion. They are (1) cereals (*burukutu*, mahewu, *pito*, *kwunu*,

ogi, *otika*), (2) fruits (*agadagidi*, cacao wine, *eketeke*, *ugba*), (3) legumes (*daddawa*, *iru*, *ogiri*, *ogboroti*), and (4) starchy root crop fermentations (*abacha*, *elubo*, *fufu*, *gari*, *loiloi*, *kokobele*).[10]

4.6 Health Benefits of Food Fermentation

Fermented foods are believed to confer enormous positive benefits that are not generally associated with unfermented foods. For a start, fermented foods yield novel bioactive compounds that are not usually found in the substrate; such compounds have been found to be immune system modulators, influence the glycemic index, possess anti-inflammatory activities, and have a potential effect on mental health. Fermented foods improves the bioavailability of certain compounds, for example, the consumption of fermented foods containing gamma-aminobutyric acid (GABA) produced *in situ* by *Lb. hilgardii* contributes to the reduction of blood pressure and anxiety, and GABA-rich red yeast rice has been reported as a strong antidepressant, whereas the use of synthetic GABA has a limited benefit due to adsorption issues. The ability of fermenting microorganisms to remove or decrease the content of harmful compounds from the raw materials and deactivation of harmful foodborne pathogens add enormous health benefits to the consumer. The fermentation product and the fermenting organism could positively influence the stomach biota and make it capable of resisting infection, improve the general gut biome health, and aid in the selective biodynamic absorption of nutrients from food.

In addition to these general functional benefits, Bevilacqua et al.[11] proposed that the ingestion of beneficial microorganisms through fermented foods may have the potential to affect and improve body responses to some stressful conditions and general well-being via a whole set of direct and indirect actions, including the following:

1. Direct protection of intestinal barrier
2. Influence on local and systemic antioxidant status and reduction in lipid peroxidation
3. Production of neurochemical compounds, such as GABA
4. Indirect influence on neurotransmitter or neuropeptide production
5. Prevention of stress-induced changes in the intestinal microbiota
6. Activation of neural pathways between the gut and brain
7. Reduced production of cytokine
8. Modulation of neurotrophic chemicals
9. Limitation of carbohydrate malabsorption
10. Improvement of nutritional status
11. Inhibition of gastric and intestinal pathogens
12. Limitation of overgrowth of bacterial growth in the small intestine
13. Analgesic properties

From the above considerations it has been established that fermentation may confer a higher level of functionality to food plants beyond their normal nutritional attributes. They lead to a marked increase of the concentration of vitamins or amino acids, a higher bioavailability of phytochemicals and minerals. Fermentation causes an improvement of the nutritional qualities of foods by increasing digestibility and removing antinutrients

(e.g., oxalate, protease and α-amylase inhibitors, lectins, condensed tannins, and phytic acid).[12] The proteolytic system of LAB may also contribute to the biochemical release of bioactive aglycones, lignans, and peptides from vegetable matrixes.

4.7 Examples of Fermented Foods with Potential Functional Benefits

4.7.1 Cereal-Based Fermented Foods

Although Africa is one of the lowest producers of cereals globally, cereals are more widely utilized as food in African countries than in the developed world (FAO).[13] Major cereals grown in Africa include maize, rice, sorghum, and millets. There is also limited production of wheat and rye. Lactic-fermented cereal-based foods and related products account for up to 80% of total calorie consumption in many African countries and they are also an important source of dietary protein. Fermented cereals are dietary staples for adults and are frequently complementary foods for young children. Fermentation has also been shown to be capable of inactivating enzyme inhibitors, such as protease and amylase inhibitors that occur widely in seed tissues, including cereal grains. Trypsin, chymotrypsin, subtilisin, and cysteine protease inhibitors are present in most major rice cultivars. They are believed to cause growth inhibition by interfering with digestion and causing pancreatic hypertrophy and metabolic disturbance of sulfur amino acid utilization (FAO).[13]

According to the FAO, fermented cereal-based food produced in Africa can be classified on the basis of either the raw cereal ingredients used in their preparation or the texture of the fermented product. The major fermented food products are grouped below according to the substrate and the texture of the finished products:

Classification on the basis of raw cereal ingredients

1. Wheat-based foods, for example, bouza, kishk
2. Rice-based foods, for example, busa
3. Maize-based foods, for example, ogi, bread, kenkey
4. Millet-based foods, for example, kunuzaki, ogi, koko, kenkey, kunu-zaki, ben-saalga
5. Sorghum-based foods, for example, pito, ogi, bogobe, kisra, burukutu, kisra, injera, kunu-zaki
6. Barley-based foods, for example, beer

Classification on the basis of texture

1. Liquid (gruel), for example, ogi, mahewu, burukutu, pito, uji, ben-saalga
2. Solid (dough) and dumplings, for example, kenkey, agidi
3. Dry (bread), for example, kisra, injera

For most parts, maize, sorghum, and millets are used interchangeably depending on availability and local custom. Various strains of *Sorghum bicolor* are fermented in Africa for the preparation of flour-based meals (ogi, kenkey) or for alcoholic beverages (pito,

burukutu). In the sorghum-producing areas of the continent, an enormous variety exists in the methods of fermentation and the products obtained from the processes. Different types of maize are consumed in Africa as staple food and are classified on the basis of their protein content and the hardness of the kernel. Much of the niacin in corn is in a bound form and this led to pellagra in areas where corn became the staple food. It was not until the late 1920s that pellagra was identified as a vitamin deficiency. The traditional practice by early native Americans of boiling corn in 5% lime or ashes releases bound niacin, making it available as a nutrient. Millets are native to Africa or Asia and have been cultivated for more than 6000 years. Millets grow well in arid regions with poor soils and are valued among the cereals for their relatively high protein content. Sorghum originated in East Africa and today is an important food crop in Africa, Asia, India, and China.

Some of the products of cereal fermentation in Africa that have significant functional roles in diet are listed below to illustrate the enormous variety they show.

4.7.1.1 Hussuwa

Hussuwa, a semisolid, dough-like food consumed in the Sudan and some communities in the Sahel region of West Africa, is prepared by mixing an equal volume of water and a liquid paste of sorghum flour and boiled to produce the thick "aceda" porridge. A further half volume of sorghum malt is added and left to ferment for up to 48 h. The resulting sourdough is cooked on a hot plate until all moisture is expelled.[14] The cooked *hussuwa* is left to ferment in an earthenware pot buried under the fireplace for up to 2 months, thereby ensuring a continuous warm temperature throughout the period to promote the mixed lactic and alcoholic fermentation,[15] finally resulting in a sweet–sour product.[16] It has been observed that the majority of the LAB strains typical of *hussuwa* fermentation were heterofermentative lactobacilli,[17] mainly *Lactobacillus fermentum* while pediococci are also present.[18]

4.7.1.2 Ogi

Ogi (akamu) is a gruel/porridge from Nigeria and other West African countries, which can be prepared from fermented maize, sorghum, or millets. Ogi is prepared by soaking corn kernels in water for 1–3 days followed by wet milling and sieving to remove bran, hulls, and germ. The pomace is sieved out while the filtrate is fermented (for 2–3 days) to yield ogi, which is a white starchy sour sediment. Ogi is often marketed as a wet cake wrapped in leaves or transparent polythene bags. It is diluted to a solid content of 8%–10% and boiled into a pap, or cooked and turned into a stiff gel called "agidi" of "eko" prior to consumption. It is a staple food throughout West Africa, where it is used as a convalescent meal in hospitals and as a weaning food for infants. Studies have shown that substantial nutrient losses occur during the various steps of *ogi* processing. Much of the protein in cereal grains is located in the testa and germ, which are usually sifted off during processing. Several microorganisms have been identified as responsible for ogi production. *Lactobacillus plantarum*, the aerobic bacteria *Corynebacterium* and *Aerobacter*, the yeasts *Candida mycoderma*, *Saccharomyces cerevisiae*, and *Rhodotorula*, and the molds *Cephalosporium*, *Fusarium*, *Aspergillus*, and *Penicillium* are the major organisms responsible for the fermentation and nutritional improvement of ogi.

4.7.1.3 Kisra

Kisra is a dietary staple of Sudan made from fermented whole sorghum flour. It is a thin pancake-like leavened bread with a very sour taste. It is prepared by mixing sorghum

flour with water to give a thick paste, which is allowed to ferment for 12–24 h, following which the paste is thinned to a desirable consistency with water just prior to baking.

4.7.1.4 Kunu-Zaki

This nonalcoholic fermented beverage is produced from the fermentation of millet and widely consumed in Nigeria. The traditional manufacturing process involves the steeping of millet grains, wet milling with spices (ginger, cloves, pepper), wet sieving, and partial gelatinization of the slurry, followed by the addition of sugar, and bottling. The fermentation that occurs briefly during steeping of the grains in water over a 8–48-h period is known to involve mainly LAB and yeasts. The product is usually consumed fresh but can be used up to 24 h without refrigeration. The shelf life can, however, be extended up to 8 days by pasteurization at 60°C for 1 h and storage under refrigerated conditions. Longer duration of about 90 days has been reported with the use of chemical preservatives.

4.7.1.5 Injera

Injera is a traditional mildly sourdough with a spongy texture made from fermented teff flour. However, it can also be prepared from fermented sorghum or other available cereals in the absence of the highly valued teff. The sorghum (or teff) grains are dehulled manually or mechanically and milled to flour, which is subsequently used in the preparation of injera. The injera dough is then baked into large, flat pancakes on a specialized electric stove or, more commonly, on a clay plate (Amharic *mittad*, Tigrinya *mogogo*) placed over a fire. Unusual for a yeast or sourdough bread, the dough has sufficient liquidity to be poured onto the baking surface, rather than rolled out. Injera resembles the French crêpe and the Indian dosa as a flatbread and is used as a base for other foods. The taste and texture are however unique—unlike the crêpe and dosa and more similar to the South Indian appam. The bottom surface of the injera, which touches the heating surface, will have a relatively smooth texture, while the top will become porous. It is the most popular baked product in Ethiopia, Eritrea, and countries in the horn of Africa. The Ethiopian national airline promotes injera on its international flights as part of an alternate cuisine. The airlines claimed: "Injere is a nutritionist's wonder grain, gluten free. Lite in calories and containing micronutrients such as calcium, magnesium, phosphate, iron, etc.… Would there be any better choice for diabetes and the calorie conscious?" The baked product is referred to by different names depending on the locality of production in Ethiopia. It is referred to as "bidena" in Oromigua, "taeta" in Giragigua, and "solo" in Walaytigna. Injera is a gluten-free cereal.

4.7.1.6 Banku

Banku is fermented staple food in Ghana, prepared from maize and/or a mixture of maize and cassava. Banku is prepared by steeping the raw material (maize or a mixture of maize and cassava) in water for 24 h followed by wet milling and fermentation for 3 days. The dough is then mixed with water at a ratio of four parts dough to two parts water or four parts dough to one part cassava and two parts water. Continuous stirring and kneading of the fermented dough is required to attain an appropriate consistency during subsequent cooking. Microbiological studies of the fermentation process revealed that the predominant microorganisms involved were LAB and molds. Banku is usually served with soup, stew, or a pepper sauce with fish. It is a favorite dish among the people of the southern Regions of Ghana, particularly the Ga tribe, but is also eaten across other regions in Ghana.

4.7.1.7 Ben-saalga

Ben-saalga is a thin porridge staple of Burkina Faso, traditionally prepared by cooking the fermented sediment of pearl millet (*Pennisetum glaucum*) in water.[19] The processing of pearl millet into ben-saulga comprises the following successive main steps: soaking the grains (first fermentation), grinding and filtration of humid flour, decanting (second fermentation), and cooking.[20] This process is considered beneficial as it can positively contribute to increased energy density of this cereal-based fermented gruel through starch hydrolysis. However, considerable losses of millet nutrients may occur, as a result of discarding the coarse particles during preparation and by leaching into the water fraction. The antinutritional components of pearl millet such as phytate were reported to be degraded by more than 50% in commercial ben-saalga, thereby facilitating the dietary uptake of proteins and minerals. The traditional production method has been successfully modified by precooking and barley malt incorporation to partially hydrolyze starch, thus allowing the preparation of high-energy-density (ED) gruels. The modifications adopted were (i) adding a precooking of 10 min after the filtration stage to gelatinize the starch in order to enable the amylase attack and/or (ii) incorporating the barley malt (amylase source) at the beginning of the decantation step at the rate of 1% of dry matter of the humid flour. The process combining both steps of modification proved highly efficient to increase the ED of gruels (on average, 440% more than that of traditional gruel) and considerably delay the start of the fermentation.[21] Cofermentation with groundnuts significantly improved the nutrient quality of the gruel.[22] *L. fermentum*, *L. plantarum*, and *Pediococcus pentosaceus* typically dominate natural fermentation. The microbes isolated from the gruel have been purified as a possible probiotic.[23]

4.7.1.8 Kenkey

Kenkey or kormi or kokoe or dorkunu is a fermented maize sourdough dumpling, which is popularly consumed as a staple dish among the Ga, Akan, and Ewe peoples of Ghana and other regions of West Africa, Guyana, and Jamaica. It is usually served with soup, stew, or sauce. During the production of kenkey, the dough is divided into two parts: one part, the "aflata" is cooked into a thick porridge, while the other uncooked part is later mixed with the "aflata." The resulting mixture is molded into balls and wrapped in dried maize husk or plantain leaves, after which it is steamed. LAB, yeasts, and molds are involved in the fermentation of kenkey. A mixed flora consisting of *Candida*, *Saccharomyces*, *Penicillium*, *Aspergillus*, and *Furasium* species were found to be the dominant organisms during the preparation of this food product.

4.7.1.9 Mahewu

Mahewu (amarewu, mabundu, mapotho) is a traditional South African beverage obtained from fermenting cereals such as maize (corn), millet, and sorghum. It can be consumed hot or cold and is commonly served as a thirst quencher, meal replacement, and weaning food. Similar beverages are also made in other parts of Africa. Mahewu is high in carbohydrates but low in high-quality protein, making it an ideal source of energy. Modern commercial mahewu is often enriched with nutrients such as protein, iron, calcium, and folate and is therefore more nutritious than the traditional version. Mahewu is also known as Mageu (the Shona and Sotho language spelling), maHewu, amaRhewu (Xhosa spelling), or amaHewu (Zulu spelling). Although it is produced now as an industrial product, home

production is still common. Its taste is derived predominantly from the lactic acid that is produced during fermentation, but commercial mahewu is often flavored and sweetened, much in the way commercially available yogurt is.

However, both traditional and commercial versions can be classified in the functional food category because they provide health benefits that go beyond their nutritional content. Some of the benefits indicated in the literature (www.theafricanpotnutrition.com) include

- *Enhanced absorption* of nutrients, especially the B vitamins (niacin, pantothenic acid, folic acid, B1, B2, B6, B12).
- *Improved digestion:* Some studies suggest that the healthy bacteria found in mahewu help the body obtain much nutrition from the diet in general. In addition, they help to prevent constipation.
- Increases *milk supply* in breast-feeding mothers.
- *Great source of probiotics:* Live microorganisms that provide the gut with good bacteria. Probiotics have been credited with positive effects on the immune system, cancers, metabolic diseases and many other health benefits.

Other commercial claims indicate that mahewu has been used for its antiviral, antibacterial, anticancer, antifungal, and antidiarrheal properties. It is traditionally prepared by adding 1 part of maize meal to 9 parts of boiling water. The suspension is cooked for 10 minutes, allowed to cool, and then transferred to a fermentation container. At this stage, wheat flour (about 5% of the maize meal used) is added to serve as a source of inoculum. Fermentation occurs in a warm sunny place within 24 h. *Streptococcus lactis* is the main fermenting organism in traditionally prepared mahewu.

Mahewu is known to offer some advantages over ogi in that the initial wild fermentation by fungi, etc. is eliminated by boiling both the maize meal and water for steeping. Furthermore, it is precooked and requires only mixing prior to consumption. Mahewu consists of coarse maize particles while ogi contains very fine pasty maize particles. The industrial production of mahewu includes the use of various LAB as starters in mahewu fermentation, including *Lactobacillus delbruckii* and *Lactobacillus bulgaricus*, which produces the most acceptable mahewu at a temperature of 50°C, disallowing the growth of unwanted microorganisms.[24] Van Noort and Spence (1976). The identity of the various organisms used in the industrial production of mahewu is still kept as a proprietary secret. In Swaziland, the mahewu known locally as Emahewu was prepared by mixing maize meal (1 kg) with water (5 L) and cooking to make a soft porridge. The cooled porridge was left to ferment at room temperature. It is reported that sugar or a peeled potato is sometimes added to aid the fermentation process.[25]

4.7.1.10 Togwa

Togwa is a sweet-and-sour nonalcoholic beverage produced from the flour of maize, sorghum, finger millet, and, sometimes, cassava tubers.[26] The chosen substrates are boiled, cooled, and fermented overnight, up to 24 h to form a porridge, which is then diluted to drink.[27] It may be fortified with herbs or micronutrients. It is a favorite energy drink in Tanzania and other parts of East Africa.

4.7.1.11 Mawe

Mawe is a staple food of Benin Republic in West Africa. It is a sourdough prepared from partially dehulled maize meal, which has undergone natural fermentation for up to 3

days. An estimated 14%–16% of total maize production in Cotonou, Benin is used for mawe production. It is used in this manner as ogi but quantitatively mawe is less important than ogi. Mawe is increasingly being produced commercially for export to neighboring West African countries. The dominant microorganisms in mawe preparation include LAB (mainly *L. fermentum* and its biotype *L. cellobiosis* and *L. brevis*) and yeasts (*Candida krusei* and *S. cerevisiae*).

4.7.2 Starchy Root Crop Fermentations

The most important root crop fermented in Africa is cassava. Processed by lactic fermentation, cassava provides a wide range of safe products such as gari, fufu, and lafun or kokonte consumed as a staple in West Africa, and kivunde and cingwada in East Africa. The fermentation of cassava removes cyanogenic glucosides, linamarin and lotanstralin, which occur in variable proportions in parts of the plant.[28] The cyanogenic glucosides are quite toxic due to hydrolytic breakdown and the release of hydrocyanic acid. The shelf life of cassava is less than 5 days with deterioration starting within 24 h after harvesting. Lactic fermentation drastically prolongs the shelf life and, for bitter cassava with high cyanogenic glucoside levels, enhances the toxicological safety. *L. plantarum* typically dominates the fermentation process and is inhibitory to many spoilage molds and bacteria.

According to Olasupo et al.,[29] the main *lactic-fermented products* obtained from cassava can be grouped into six categories on the basis of the texture of the final product (e.g., paste, powder, granules, cake):

- Fermented mashes, such as fufu and akpu
- Fermented flours, such as lafun, kanyanga, and luku
- Smoked fermented balls, such as kumkum and pupuru
- Steamed and fermented chips, such as chikwangue and ntuka
- Roasted grits, such as gari, agbelima, kapok, and popogari
- Steamed grits, such as attieke

4.7.2.1 Fufu

Fufu is a staple fermented food in West and Central Africa. It is produced from peeled cassava that is soaked and allowed to ferment for up to 5 days. The fermented cassava is then mashed and sieved through a cotton bag and allowed to settle. The paste, known as "fufu," is wrapped in plantain leaves in balls until ready for cooking. It is thinned down and put on a low fire with constant stirring, to prevent burning, until it is cooked to a thick gel. It is consumed with soup, sauce, or stew.

4.7.2.2 Garri

Garri is the most widely consumed form of cassava meal in most parts of West Africa. It involves the grinding of cassava, which is then allowed to ferment for about 3 days after which the water is squeezed out. The product is then roasted into dry flour or granules. Palm oil may be added during the frying process to produce garri with various shades of yellow/gold color. This flour is known as garri, and can be eaten in this form or made into "eba." Eba is derived from the mixture of boiling water and garri to form a soft paste.

4.7.2.3 Lafun

Lafun (*elubo* or kokonte) is a cassava meal that is prepared by soaking the peeled cassava for 3 days, after which it is then grated and allowed to dry in the sun. The product is then ground into a very fine powder. It can be stored in this form, and when eating, an estimated amount of boiling water is mixed with an estimated amount of Lafun flour. It is allowed to cook and is stirred continuously to ensure consistent texture and prevent any lump formation and charring. The lafun fermentation is dominated by *L. fermentum*, *L. plantarum*, and *W. confusa*. In contrast to solid-state fermentation, gari, fufu, and lafun are produced in a submerged fermentation of cassava roots, followed by washing, dewatering, drying, and milling to obtain cassava flour.

It has been observed that the efficiency of cyanide removal from cassava depends on the processing technique used and the extent of processing. Processing operations such as fermentation, boiling, cooking, roasting, and drying have been shown by several studies to be able to reduce the cyanide content of cassava to acceptable safe levels, if they are correctly conducted and combined. In addition, other hazards such as mycotoxins and pathogenic bacteria can also be controlled through proper processing.[30]

4.7.2.4 Attiéké

Attiéké is a steamed granular meal derived from fermented cassava in Côte d'Ivoire. It is a couscous-like product, with a slightly sour taste and whitish color. *Attiéké* is produced from fermented grated cassava, dewatering the mash, followed by sieving, granulating, sun-drying, and steaming of the granular product. There is enormous variation in the method of processing among the various ethnic groups; however, a standardized reference product showed the best sour and sweet taste, expressed by high reducing sugars content (46.25 mg/100 g) and low lactic (59.9 mg/100 g) and acetic acids (10.03 mg/100 g) content. Attiéké produced in the Adjoukrou and Alladjan zones of Côte d'Ivoire were found to be similar in sensory, physical, and biochemical characteristics to the reference standard.[31]

4.7.3 Fermentation of Legumes, Seeds, and Nuts

Plants of the family Leguminosae (Fabaceae) yield many edible pulses, which include peas, beans, lentils, peanuts, and other podded plants. These legumes are staples in many African countries and many are valued for their enormous health benefits. Apart from providing an excellent source of macronutrients such as protein, dietary fiber, fatty acids, and carbohydrates, legumes are also rich in micronutrients and phytochemicals.[32] Fermentation of the legumes yield various peptides, amino acids, and physiologically active phytochemicals. As discussed earlier, the fermentation of legumes improves the availability of many phytochemicals. Most traditional food flavors used as condiments in many African cuisines are produced by the fermentation of legumes.

Studies of food condiments and seasonings prepared from three legumes, locust bean, Bambara nuts, and soybean have showed that the condiments possess antioxidant, antihepatotoxic, and antidiabetic properties. It was found that diabetic untreated rats showed elevated levels of alanine aminotransferase (AST), aspartate aminotransferase (ALT), and alkaline phosphatase (ALP), and malondialdehyde ($P < 0.05$) with reduced activities of glutathione-*S*-transferase, catalase, as well as plasma-reduced glutathione, vitamin C, and total protein content. However, treatment of diabetic rats with fermented legume condiment diets for 14 days ($P < 0.05$) reversed the above parameters toward normalcy, suggesting their possible use as functional foods.[33]

4.7.3.1 Examples of Fermented Legumes, Seeds, and Nuts as Food Condiments

4.7.3.1.1 Dawa-Dawa

Dawa-Dawa (Iru, Yoruba, Ogiri Igala, Igbo) is a food condiment prepared from the fermentation of the African locust bean (*Parkia biglobosa* or *Parkia filicoideu* Welw). It is produced by boiling locust bean seeds for up to 48 h to soften the hard seed coats after which they are dehulled by hand or by gentle pounding. The separated kernels (cotyledons) are boiled in water with "kanwu" (potash) for 2 h to soften them. The boiled cotyledons are spread in a raffia basket lined with blanched banana leaves and the cotyledons are covered with several layers of banana leaves and left to ferment for 2–3 days at the prevailing temperature of the day. Wood ash may be added. The fermented product is then sun-dried for l–2 days yielding a dark brown or black product. An alternative production method involves the sun-drying of the mass and making it into a paste of varying shapes and textures depending on the custom of the ethnic group consuming it.[34] In the fermentation of *Parkia biglobosa* in the Benin Republic to produce yanyanku and ikpiru, the condiments are made by the fermentation of Malcavene bean (*Hibiscus sabdariffa*) as functional additives for the African locust bean fermentations.[35]

4.7.3.1.2 Ogiri-Egusi

"Ogiri-egusi" is a popular condiment used in the south-east region of Nigeria for flavoring in sauces, soups, and stews. It is prepared from the fermentation of melon seed (*Citrullus vulgaris* Schrad).[36] The method of preparation involves dehulling and moistening of the melon seeds. The cotyledons are boiled for 2–3 h before being wrapped tightly in layers of blanched plantain leaves, and left to ferment at the prevailing ambient temperature for 3–5 days. The fermented seeds are ground into a paste with ash from burnt oil palm leaves and palm shaft is added to impart a gray color to the paste. The paste is molded in small portions into leaves, wrapped up and left near the hearth (fireplace) until the unique (characteristic) aroma of "ogiri-egusi" is obtained. The principal fermenting organisms include *Bacillus subtilis*, *Bacillus megaterium*, *Bacillus jirmus*, *Escherichia*, *Proteus*, *Pediococcus*, and *Alcaligenes* spp.[37,38]

4.7.3.1.3 Agborotii or "Ogbaratii"

Agbarotii is the product of a mixture of fermented African oil egusi seed used as a delicacy and occasionally as a soup flavoring. The preparation process consists of the separate fermentation of oil bean seeds and egusi seeds for 3 days. Equal measures of the two are mashed together to make a paste. The paste is distributed in small portions into blanched leaves, which are wrapped and placed near the fire for proper flavor development, giving rise to "ogboroti."[39]

4.7.3.1.4 Ogiri-isi

Ogiri-isi, "ogiri-igbo," or "ogiri-agbor" is a condiment with a very intense characteristic aroma prepared from fermented castor seeds (*Ricinus cummunis*) and used as flavoring in soups and stews in eastern Nigeria. It is prepared by boiling the dehulled castor seeds wrapped in blanched plantain leaves for 6–8 h. It is then left to ferment for 4–6 days. After this, the seeds are mixed with ash from burned palm leaves and then ground into a paste. The resultant paste is rewrapped and left for another 3 days near the fire to develop the characteristic flavor (aroma) of "ogiri-isi." A similar condiment can also be prepared from the seeds of fluted pumpkin (*Telfairea occidentafis*).

4.7.3.1.5 Daddawa

"Daddawa" is a food condiment obtained from fermented soybean (*Glycine max* Merrill) or pawpaw (*Carica papaya*) and used in northern-central regions of Nigeria as a flavoring for soup and stew. The method of production involves the overnight soaking of sorted, cleaned, and washed soybean. The cotyledons are washed after the removal of the seed coats, which are peeled off by hand. The cotyledons are thereafter boiled in water in an earthenware or aluminum pot for 2–3 h after which the excess water is decanted. The boiled cotyledons are wrapped with blanched plantain leaves and placed inside a calabash container already lined with blanched plantain leaves. This is left to ferment at room temperature for up to 5 days. The fermented product is pounded and used as needed or smoked prior to pounding into flour.

4.7.3.1.6 Ugba

"Ugba" is the product of the fermentation of the large brown glossy seeds of the African oil-bean (*Pentaclethru macrophylla*) which is used by the Igbo and some other ethnic groups in southern Nigeria as a delicacy and soup flavoring.[40] The production of "ugba" from the oil bean begins with the boiling of the oil bean seeds in a metallic pot over an open fire for 4–12 h to soften the hard brown testa (called the shell). The shells are removed and the cotyledons are washed. The cotyledons are boiled in water overnight over a low flame. They are allowed to cool, drained, and washed with cold water several times. The washed cotyledons are sliced into long thin slices. These slices are mixed with salt, wrapped in small packets with leaves, and lightly tied. These are placed in a basket to ferment at room temperature for 2–5 days to yield "ugba." A 3-day fermentation provides the delicacy,[41] while 5 days of fermentation produces the soup condiment.[42] Ugba is used as salad mixed with vegetables, spices, and fish. In addition to the probiotic potential of Ugba, it is a source of non-protein amino acids, and in its use as salad ingredient, it can be fortified with micronutrients as needed.

4.7.3.1.7 Kpaye

This is a condiment obtained from the fermented seeds of *Prosopis africana* for up to 120 h. The fermenting organisms have been identified to be *Bacillus subtilis*, *Bacillus licheniformis*, and *Bacillus pumilus*. Like the production of flavor condiments "Kpaye" production involved a rise in pH, moisture content, and total free amino acids, while titratable acidity and reducing sugar decreased gradually after 24 and 72 h of fermentation, respectively.[43]

4.7.4 Fermented Fruits

4.7.4.1 Agadagidi

The soft, overripe banana/plantain can be fermented to yield a delicious beverage called "agadagidi." It is consumed in West Africa, especially in south-west Nigeria as a nourishing drink. The method of preparation is as outlined by Uzogara et al.,[39] Abiose and Adedeji,[44] and Iwuoha and Eke.[10] It consists of fermenting peeled, sliced plantains/bananas in an earthenware pot with water. The pot is covered tightly and allowed to ferment at room temperature for a period of l–5 days after which the juice is strained and used as a refreshing drink.

4.7.4.2 Eketeke

One of the most intriguing African fermentation products is the rancid eketeke, produced by the fermentation of palm oil, which is traditionally used in the preparation of "ugba"

(fermented African oilbean seeds) salad. According to Uzogara et al.,[39] the production of eketeke involves leaving freshly harvested oil palm bunches in the shade and covering completely with palm fronds/leaves for 1 week to ferment. The fruits are removed, cleaned, and pounded into a cake in a mortar and pestle. The cake is dry-heated in an open cast iron pan, and finally pressed to release the slightly rancid oil with a characteristic flavor.

4.7.4.3 Fermented Cocoa Sap

Cocoa (*Theobroma cacao*) is better known as source of cocoa powder and chocolate derived from the seeds. However, among cocoa-growing communities, another highly valued product from cocoa is obtained from the fermentation of the sap. It is a common traditional alcoholic beverage consumed in the Cross River, Oyo, Ondo, and Ogun states of Nigeria, and in some cocoa-growing countries in West Africa. It is prepared by harvesting the sugary pulp during the removal of the seeds from cocoa pods. The fleshy pulp is allowed to ferment for 5–6 days in a raffia palm basket covered with leaves. The fleshy cocoa pulp solubilizes and the seeds are released; the sap (from the pulp) drips from the porous baskets into a calabash/earthenware pot. The full biochemical analysis of the sap and/or the fermented product has not been reported but all parts of the cocoa pod are rich in antioxidant polyphenols.

The cocoa beans used for the production of chocolate and cocoa powder are actually fermented using the above traditional process before processing and storage as cocoa beans. In a study to determine the fermentation dynamics of cocoa in heaps and in boxes, 106 yeasts, 105 LAB, and 82 AAB were isolated as viable counts, and were identified by means of rep-PCR grouping and sequencing of the rRNA genes.[45] The study found that during the box fermentations, the most abundant species were *S. cerevisiae*, *Candida ethanolica*, *L. fermentum*, *L. plantarum*, *Acetobacter pasteurianus*, and *Acetobacter syzygii*, while *S. cerevisiae*, *Schizosaccharomyces pombe*, *Hanseniaspora guilliermondii*, *Pichia manshurica*, *C. ethanolica*, *Hanseniaspora uvarum*, *L. fermentum*, *L. plantarum*, *A. pasteurianus*, and *Acetobacter lovaniensis* were identified in the heap fermentations. Furthermore, the most abundant species were molecularly characterized by analyzing the rep-PCR profiles. Strains grouped according to the type of fermentations and their progression during the transformation process were also highlighted. As would be expected, the effect of temperature and moisture on the growth of these microorganisms directly impact the quality of the final product.

4.7.4.4 Maari

Maari (higgi, issai, or dikouanyouri) is a food condiment obtained by the spontaneous fermentation of baobab seeds in Burkina Faso, Benin, Mali, Nigeria, and other neighboring West African countries. There is enormous variety in the traditional preparation of maari among the different communities in West Africa. The general method of preparation consists of boiling cleaned baobab seeds for about 2 days (at least 36 h), with ash lye (alkaline) solution added after 24 h to aid in the softening of the seeds. At the end of the boiling period, the seeds are drained and transferred into a basket or similar receptacle and left to ferment spontaneously (i.e., first fermentation) for 48 h at room temperature. The fermenting mash is usually pounded in a wooden mortar and molded with further addition of alkaline ash lye solution. It is then left to undergo a second spontaneous fermentation for approximately 24 h at room temperature. The fermented product will then be molded, steam cooked, and sun dried. When ready to be used as flavoring in stews, soups, sauces, and other foods, maari is steeped in warm water for a few minutes.

The chemical changes that occur during the fermentation of baobab seeds for production of maari have been reported.[46] According to Parkouda et al.,[46] there is "a wide variety of free amino acids including essential amino acids in the unfermented seeds. Fermentation led to an increase in the concentration of total free amino acids from 16.03 nmol/mg in unfermented seeds to 113.24 nmol/mg after 60 hours of fermentation followed by a decrease thereafter. Fluctuations in the concentrations of each compound were observed during the fermentation period. Differences were also observed in the final products from different production sites. The output of the oil extraction was 11.5%–25.8%. A total of seven fatty acids were identified, with oleic acid being quantitatively the major fatty acid. The results showed a much higher concentration of unsaturated fatty acids than saturated fatty acids. The preponderant fatty acids were oleic, linoleic, palmitic, and stearic acids. These four fatty acids constitute approximately 90% of the composition of maari."

4.7.4.5 Owoh

Owoh is a popular food condiment prepared by the fermentation of cotton seed. Owoh has a strong but pleasant aroma and it is used in southern Nigeria to flavor soups, stews, and sauces. Cotton seeds are not edible because of the presence of gossypol, which inhibits digestion and may possess spermicidal properties. Cotton seeds are however rich in proteins and other useful phytochemicals and the production of owoh appears to be a traditional method to detoxify cotton seed. The traditional method for the preparation of owoh is as described by Sanni and Ogbonna.[47] It consists essentially of boiling the seeds for about 2 h until they soften. The seeds are transferred into cold water, soaked overnight, and then manually washed to remove the seed coat. The cotyledons are then wrapped in banana leaves in packets and boiled for about 2 h. The packets after boiling are drained of all liquid and placed in a calabash wrapped in jute bags. They are allowed to ferment for about 3 days to yield a dark-brown, semisolid substance with a pungent smell that is used as a condiment.

The traditional fermentation of owoh is dominated by the presence of *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus pumillus*, and *Staphylococcus* spp. The deliberate use of combinations of isolated *Bacillus* spp. with and without *Staphylococcus* spp. as a starter culture in a controlled fermentation of cotton seed produced owoh of good quality.[48]

4.7.5 Fermentation of Palm Wine and Raffia Palm Wine

The mildly fermented sap of raffia palm (ngwo) or oil palm (nkwu) yields a sweet refreshing drink collectively called "palm wine." It is obtained by the tapping of the inflorescence of these palm trees. The sugary sap when not consumed immediately or within 12 h of collection from the tree begins to ferment. The fermentation is complete in about 2 days, giving rise to a milky suspension of microorganisms in a fermented sap that tastes sour and harsh. When the fermentation is allowed to proceed to up to 5 days, the alcoholic content can be distilled to yield "ogogoro" or "ekpeteshi," a highly alcoholic liquor. Ogogoro has a gin-like taste unlike fermented palm wine that has slight vinegary flavor in its peculiar taste. Fermented palm wine is a rich source of yeasts and LAB.

4.7.6 Fermentation-Derived Virgin Coconut Oil

The coconut tree (*Cocos nucifera* L.) yields two oils from its fruit: coconut oil obtained from the dried coconut or copra and virgin coconut oil (VCO), which is a product of the fresh

coconut flesh without the application of heat or chemical processes. The production of VCO involves the separation of oil from coconut milk. Coconut milk can be obtained by either pressing fresh coconut flesh without additional water or grating the coconut flesh followed by the harvesting of the water–oil emulsion. The oil can be separated from the emulsion by means of fermentation, enzymatic extraction, refrigeration, or mechanical centrifuge.[49] VCO possesses superior antioxidant activity compared to copra oil.[50] The fermentation of the coconut milk or emulsion has yielded many therapeutically useful formulations. The quality and functionality of VCO are largely dependent on the method of separation of the oil from the water–oil emulsion. Separation by fermentation followed by decantation yields superior VCO. The separation can also be accomplished by breaking the emulsion and creating an oil–oil emulsion, in which pure coconut oil is added to the coconut milk to extract the oil from the emulsion, followed by separation of the oil from the water and protein via decantation. The process requires 24–48 h, yielding about 40% of the oil available in the coconut.[51] VCO is rich in short- and medium-chain fatty acids, as well as polyphenolics.

4.8 Fruit and Vegetable Smoothies

A growing trend in most African countries is the preparation of exotic smoothies that consist of mixtures of fruits and vegetables processed to pulp or puree. The possible variation in the formulation is endless with some of the brands, including nuts, spices, and medicinal herbs. Lactic acid fermentation by autochthonous selected starters positively affects the content of antioxidant compounds and enhances the sensory attributes of smoothies. Cocoa, *Garcinia kola*, turmeric, ginger, grains of paradise, peppers, *Aloe vera*, and other antioxidants improve the nutritional, claimed health-promoting properties, and sensory features of the smoothies. Likewise, several African vegetable purees fermented by *Lactobacillus* spp. for the production of functional foods are enriched in phenolic derivatives with increased bioavailability and biological activity. Another addition to the growing list of African foods is the mixture of fruits and vegetables with traditional dairy products.

For example, mutandabota, a nonfermented milk-based food consumed daily as a major source of proteins and micronutrients, and sometimes used as a weaning food for infants in Southern Africa, is increasingly being used as a platform to introduce micronutrients into the rural diet. The product is traditionally made by mixing raw cow or goat's milk 79% (wt/wt), dry baobab (*Adansonia digitata* L.), fruit pulp 14% (wt/wt), and sugar 7% (wt/wt).[52] Mutandabota has a thick, yogurt-like consistency, a sour taste, and a pH of 3.4 ± 0.1. Although such products with low pH are generally regarded as microbiologically stable and safe to eat, a recent improvement to this functional food is the technique of using pure well-characterized microbial cultures. A variant of mutandabota fermented with the probiotic *Lactobacillus rhamnosus yoba* (yoba mutandabota) is gaining wide acceptance throughout East and Southern Africa. It has been investigated by challenging the products with five important food pathogens: *Listeria monocytogenes*, *Salmonella* spp., *Campylobacter jejuni*, *Escherichia coli* O157:H7, and *Bacillus cereus*.[53] The results indicated that that mutandabota fermented with *L. rhamnosus yoba* has antimicrobial properties against the tested pathogens and is safer compared to the traditional mutandabota.

Plants that are normally consumed as "teas" such as kinkiliba (*Combretum micratum*), lemon peel, African bush tea, and rooibos (*Aspalathus linearis*) are often fermented longer than the period required for curing the raw leaves, with or without starter cultures to produce designer teas that serve as detoxifying drinks, antiobesity remedies, functional foods, and general wellness teas.

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Section II

Functional Foods in the Management of Certain Diseases



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5

Oxidative Stress, Plant Antioxidants, and Health

5.1 Introduction

Human cells, as part of their normal metabolism, generate free radicals in the natural process of producing energy. The production of cellular energy is essential for the normal functioning of the body. Even the smallest physical activity that we take for granted, such as lifting our arm, breathing, and blinking our eyes, requires the generation of ATP by the cells. In the process, a lot of free radicals are generated as part of the body's metabolism and defensive processes. The free radicals that can be formed within the body include the superoxide anion (O_2^-), the hydroxyl radical (OH·), singlet oxygen ($^1O_2$), and hydrogen peroxide (H_2O_2). Superoxide anions are formed when oxygen (O_2) acquires an additional electron, leaving the molecule with only one unpaired electron. Within the mitochondria, O_2^- is continually formed, and the rate of formation depends on the amount of oxygen flowing through the mitochondria at any given time. Hydroxyl radicals are short-lived, but are the most damaging radicals within the body. They can be formed from O_2^- and H_2O_2 via the Haber–Weiss reaction.[1] The oxidation of carbohydrates, fats, and proteins to produce energy through both aerobic and anaerobic processes can also lead to the production of free radicals. The progression of aerobic metabolic processes, such as respiration and photosynthesis, inevitably leads to the production of reactive oxygen species (ROS) in mitochondria, chloroplasts, and peroxisomes. The mitochondrial respiratory chain, under hypoxic conditions, also produces nitric oxide (NO), which can regenerate reactive nitrogen species (RNS). Excessive lipid peroxidation can also lead to the formation of reactive aldehydes such as malondialdehydes and 4-hydroxynonenal. Other reactive species that may be injurious to the body include reactive molecules generated from the metabolism of carbohydrates, fats, and proteins.

These free radicals in excess concentrations can be toxic, and over time, can overwhelm the system and lead to many diseases, including several inflammatory conditions, mutagenesis, and cellular diseases. ROS and other radicals are also involved in diabetes, cancer, liver disease, aging, arthritis, AIDS, macular degeneration, and autoimmune, inflammatory, cardiovascular, and neurodegenerative diseases. The defense against free radicals are mediated through a class of naturally occurring substances called antioxidants. Antioxidants prevent ROS concentrations from reaching a damaging level and have been considered as a promising therapy for the prevention and treatment of these diseases. Fortunately, the body has evolved a variety of mechanisms to neutralize the effects of these free radicals when they are not needed. They include vitamin E, vitamin C, and coenzyme Q10, as well as flavonoids, polyphenols, anthocyanins, superoxide dismutase, and catalase, which enable the body to quench the generation of free radicals without

affecting the ability of the body to generate ATP energy and also inhibit the generation of toxic levels of free radicals themselves.

The phytochemicals in food plants supplement the natural antioxidants of the body and provide protection against damaging oxidative processes. Several studies have shown that phytochemicals are capable of reversing many of the processes that underlie many metabolic and chronic diseases.[2] These dietary antioxidants can sacrificially scavenge ROS/RNS and thereby prevent their buildup and indirectly reverse the progression of diseases associated with the oxidative processes. The classes of phytochemicals that have been shown to possess antioxidant properties are quite diverse and include aromatic acids, lignans, flavonoids and biflavonoids, alkaloids, phenolics, organosulfur compounds, carotenoids, and several nitrogen-containing compounds (Table 5.1). Many African functional foods have shown varying degrees of antioxidant activities and these are discussed in the sections that follow.

These substances assert their antioxidant activities through multiple pathways, including scavenging species responsible for oxidation initiation or *preventive antioxidants*; interruptors of the propagation of the autoxidation chain reaction or *chain breaking antioxidants*; singlet oxygen quenchers; synergists or compounds increasing the activity of chain breaking antioxidants in a mixture; reducing agents; metal chelators, which stabilize metal prooxidants (iron or copper cations); and inhibitors of specific oxidative enzymes (especially lipoxygenases).

The observed differences in the incidence of neurodegenerative diseases (NDD) in different countries with markedly different dietary habits gave the first indication that food and environmental factors have a role in the prevalence status of these diseases. Spices, antioxidants, small-chain fatty acids (e.g., virgin coconut oil, aromatic oils), and flavonoids are beneficial in the prevention of NDD. High polyphenolic foods are regarded as good sources of antioxidants. These include onions, tomatoes, green and black tea, virgin coconut oil, cocoa and dark chocolate, black-eyed beans and other pulses, peppers, pomegranate, fenugreek seeds, okra, sorghum, ofada rice, bambara groundnut, cowpea proteins, and numerous fruits and vegetables. Although multiple factors are involved in the development of various neurodegenerative diseases, including Alzheimer's disease (AD), Parkinson's disease (PD), multiple sclerosis, brain tumor, and meningitis, oxidative imbalance and chronic inflammation are considered key components in the pathogenesis of such diseases. Natural antioxidants when present even in trace amounts are capable of inhibiting the initiation step of these diseases by inactivating or scavenging free radicals. Two neurodegenerative diseases, AD and PD, are used below to illustrate the possibilities that exist in the use of functional foods with antioxidant properties in the management of certain chronic diseases. Other diseases in which oxidative stress is believed to play a role are discussed in other sections of this book.

5.2 Alzheimer's Disease

AD is a poorly understood neurological disorder that affects a larger number of elderly people, especially those above the age of 85 years. With the phenomenal increase in life expectancy in most countries, the number of people affected by dementia is becoming a public and socioeconomic concern in many countries all over the world, independent of economic conditions. The most common features of this neurodegenerative disorder includes the following: (a) polygenic/complex disorders in which genetic, epigenetic, and

TABLE 5.1

Naturally Occurring Antioxidants and Their Health Benefits

Antioxidant		Health Benefits
Vitamin C (Ascorbic acid)		Most effective, least toxic, water-soluble antioxidant in mammalian systems. It is of great interest due to the possibility of increasing the resistance of plasma-to-lipid peroxidation in the case of short- and long-term supplementation,[12] in lowering serum uric acid levels, resulting in a correspondingly lower incidence of gout,[13] significantly decreases the risk of having a stroke,[14] and reduces the incidence of chronic and degenerative diseases.[15] Evidence suggests preventive role in cataract formation.[16]
Vitamin E (α-tocopherol)		Vitamin E is a natural lipid-soluble antioxidant, can inhibit lipid peroxidation, which helps to preserve membrane integrity and critical membrane functions.[17] It is believed to be the primary components of the antioxidant system of the spermatozoa,[18] and in combination with omega 3 fatty acids it has beneficial effects on coronary artery disease patients by increasing gene expression of SIRT1 and PGC1α and improving oxidative stress and inflammation in these patients. Epidemiological studies indicate that vitamin E decreases the risk of ischemic stroke, suggesting that stroke might be prevented through the use of vitamin E and other antioxidants.[14]
Riboflavin (Vitamin B2)		Riboflavin is an essential component of the coenzymes flavin mononucleotide and flavin adenine dinucleotide and is contained in numerous foods in free and mainly in conjugated forms. Vitamin B2 is one of the nutrients that does not function directly as antioxidants but are co-factors for the antioxidant enzymes in the eye. Paradoxically, the compound is an effective trigger of reactive oxygen species and may induce photosensitized damage of food constituents, such as amino acids, proteins, vitamins, and antioxidants (polyphenols and flavonoids).[19]
Tocotrienol		Tocotrienols are structurally related to the tocopherols (vit. E) but differ from the latter enormously in possessing superior anti-inflammatory and antioxidant properties. Tocotrienols, but not tocopherols, block the processing and nuclear localization of sterol regulatory element binding protein-2, the transcriptional factor for HMG CoA reductase and FPP synthase, and enhance the degradation of HMG CoA reductase. Consequently, tocotrienols deplete the pool of FPP and GGPP and potentially blunt prenylation-dependent AD pathogenesis. The anti-inflammatory activity of tocotrienols further contributes to their protection against AD. The mevalonate- and inflammation-suppressive activities of tocotrienols may represent those of an estimated 23,000 mevalonate-derived plant secondary metabolites called isoprenoids, many of which are neuroprotective. Tocotrienol-containing plant foods and tocotrienol derivatives and formulations with enhanced bioavailability may offer a novel approach in AD prevention and treatment.[20] They also possess antiproliferative,[21] antiosteoporotic,[22] antihepatotoxic[23] properties and in the treatment of diabetic nephropathy.[24]
Carotenoids (carotenes and xanthophylls)		Carotenoids are red, orange, and yellow isoprenoid polyene pigments produced by bacteria, algae, and plants. More than 700 carotenoids exist naturally, and an annual bioproduction of 100 million tones makes carotenoids among the most widespread and largest groups of pigments in nature.[25] Carotenoids have been shown to play a range of roles in the prevention against various health disorders, including cancer, metabolic disease, and possibly cardiovascular disease.[26] Beneficial in the prevention of cardiovascular diseases among the elderly.[27]
Carotenoids	β-Carotene	It has been reported that β-carotene is associated with positive influence on certain types of cancer[28] and cardiovascular diseases.[29]
	Lycopene	Lycopene prevents several pathologies, such as cardiovascular disease,[30] obesity,[31] and some cancer types.[32]

(*Continued*)

TABLE 5.1 (*Continued*)

Naturally Occurring Antioxidants and Their Health Benefits

Antioxidant	Health Benefits
Carotenoids–xanthophylls	Lutein and zeaxanthin are strongly associated with visual health and are also involved in reducing the risk of developing cardiovascular diseases.[33]
Polyphenols	
Catechins	The main antioxidants in green teas and several leafy vegetables.[34] It has been shown to be beneficial in a variety of diseases. Recent studies on humans suggest that green tea may contribute to a reduction in the risk of cardiovascular disease and some forms of cancer, as well as to the promotion of oral health and other physiological functions such as antihypertensive effect, body weight control, antibacterial and antiviral activity, solar ultraviolet protection, bone mineral density increase, antifibrotic properties, and neuroprotective properties.[35]
Flavonoids	Flavonoids have been shown to be anti-inflammatory, antidiabetic, and useful in cardiovascular diseases. The intake of flavonoids is inversely associated with subsequent cancer.[36,37]
Flavonols	Studies have shown that quercetin, which is the major flavonol present in onions, exhibits anticancer, anti-inflammatory, antiviral activity, and may also prevent cardiovascular disease in humans.[38,39]
Flavones	Flavones have antioxidant,[40] antidiabetes,[41] anticancer, anti-inflammation,[42] neuroprotective,[43] antipeptic-ulcer,[44] and antimicrobial effects.[45]
Flavanones	As a flavanone, naringenin exhibits antioxidant and antidiabetic activity[46] as well as demonstrating antiproliferative properties in cervical cancer.[47] Naringenin inhibits gastrointestinal smooth muscle contractility in isolated animal tissues,[48] and chloride secretion in isolated colonic epithelia.[49] This compound has a wide spectrum of pharmacological properties such as anti-inflammatory, anticarcinogenic, antihypertensive, and anti-atherogenic.[50]
Biflavonoids	Dimeric flavonoids based on naringenin, eridictoyl, and taxifolin moieties exhibit pronounced antioxidant, antiviral, and anti-inflammatory properties.
Flavanols (flavan-3-ols)	Flavanols poses antioxidant, anti-thombotic, anti-inflammatory, and anti-proliferative activities, as well as inhibition of pathogenic bacteria and modulation of lipid metabolism.[51]
Anthocyanins	Anthocyanins exert beneficial effects on humans; they exhibit antioxidant and anticarcinogenic activity,[52] play a vital role in the prevention of neuronal and cardiovascular illnesses, cancer, and diabetes.[53,54] It has been established that the administration of anthocyanins for 4 weeks decreases myopia, apoptosis, diabetes, and obesity symptoms.[55] The antioxidant potential of anthocyanins depends on the chemical structure of the molecule, the phenolic structure giving antioxidant properties.[56]
Isoflavones	Isoflavones have a large spectrum of functional benefits on the human body, such as reduction of cardiovascular risk, postmenopausal symptoms,[57] and cancer.
Phenolic alcohols	Hydroxytyrosol and tyrosol exert an in vitro protective effect against low-density lipoprotein (LDL) oxidation and at low concentration have been found to protect human erythrocytes and DNA against oxidative damages.[58] Hydroxytyrosol is one of the few nutraceuticals approved by the E. F. S. A. (2011) for its ability to maintain healthy LDL cholesterol levels and lipid antioxidation.
Phenolic acids	Phenolic acids are powerful antioxidants and have been reported to demonstrate antibacterial, antiviral, anticarcinogenic, anti-inflammatory, and vasodilatory actions.[59]
Tannins	Tannins have been reported to have diverse pharmacological activities, including, antibacterial,[60] anti-thrombotic, anti-atherogenic,[61] anti-mutagenic, antidiabetic and anti-proliferative effects, anti-carcinogenic, anti-inflammatory,[62] and antiviral properties.[63]

(*Continued*)

TABLE 5.1 (*Continued*)

Naturally Occurring Antioxidants and Their Health Benefits

Antioxidant	Health Benefits
Stilbenes	Stilbenes have antioxidant and antimicrobial efficiency, prevent cardiovascular disease, arteriosclerosis, and cancer and act as anti-inflammatory[64] and antiviral agents.[65]
Lignans	Lignans are antioxidants and they play a role in normal colon functioning, and inhibit/delay the growth of experimental mammary cancer.[66] They also possess, anti-hepatotoxic,[67] anti-aging,[68] antidiabetic and analgesic properties,[69] as well as wound healing,[70] anti-hyperlipidemic,[71] and prevention of atherosclerotic cardiovascular diseases.[72]
Peptides and Proteins	Peptides and proteins found in pulses and vegetables have significant antioxidant activities.[73] For example, four antioxidant peptides have been identified from a simulated gastrointestinal digest (Id) from *Amaranthus mantegazzianus* proteins[74]; from bran[75]; from defatted walnuts[76], and from legumes and pulses.[77]

environmental factors are involved, (b) deterioration of higher activities of the central nervous system (CNS), (c) multifactorial dysfunction in several brain circuits, and (d) accumulation of toxic proteins in the nervous tissue.

It is also characterized by severe neuronal loss and proliferation of plaques composed of β-amyloid peptide (Aβ) and tau protein deposits. It is believed that it is the imbalance between production and clearance of these proteins, leading to the aggregation of Aβ peptides, especially in neurotoxic forms, that may be the initiating factor in AD.[3] The absence of an effective therapeutic approach could be due to inadequate knowledge of AD physiopathology and the lack of early diagnosis. Other drawbacks include poor bioavailability or limited BBB arising from tested molecules in the current or new therapeutic strategies, and the low level of translation of the results of mechanism-based assay results into therapeutically useful molecules.

There is therefore no acceptable drug therapy but several approaches have been advocated, which consist of treating the various physiological manifestations of AD. The polypharmacy approach uses different therapeutic interventions for the associated memory decline, behavioral changes, functional decline, and other related or concomitant pathologies. Recent studies have suggested that several natural products,[4] including a number of African functional foods, may be beneficial in the management of AD by the prevention of Aβ buildup in the first place, which precedes NDD and the amelioration of further decline in cognitive functionality. These include the following:

- Drumstick tree (*Moringa oleifera*)
- Phytoestrogens (e.g., from pigeon pea, *Cajanus cajan*)
- Walnut extract
- *Erigeron annuus* leaf extracts
- Epigallocatechin-3-gallate (found in various teas)
- Luteolin
- Brown algae (*Ecklonia cava*)
- Gami-chunghyuldan (standardized multiherbal medicinal formula)
- *Punica granatum* extracts

- Ginkgo/maidenhair tree (*Ginkgo biloba*)
- Sicklepod (*Cassia obtisufolia*)
- Sal leaved desmodium (*Desmodium gangeticum*)
- Lemon balm (*Melissa officinalis*)
- Garden sage, common sage (*Salvia officinalis*)
- Alkaloids from the Calabar bean (*Physostigma venenosum*)
- Huperzine A from *Huperzia serrata*
- Galantamine from the snowdrop *Galanthus woronowii*
- Cannabinoids (cannabidiol) from *Cannabis sativa*
- Saffron (*Crocus sativus*)
- Ginseng (*Panax* spp.)
- Sage (*Salvia* spp.)
- Lemon balm (*Melissa officinalis*)
- *Polygala tenuifolia*

Enhancement of acetylcholine levels in the brain is believed to be one of the means for the treatment of AD. Extracts of the South African plants *Salvia tiliifolia* Vahl. (whole plant), *Chamaecrista mimosoides* L. Greene (roots), *Buddleja salviifolia* (L.) Lam. (whole plant), and *Schotia brachypetala* Sond. (root and bark) have been shown to possess strong acetylcholinesterase inhibitory (AChEI) activity, as well antioxidant properties as indicated by the measurement of their polyphenolic content and antioxidant activities. The DPPH and ABTS assays were used to determine antioxidant activity and the Ellman colorimetric method to quantify AChEI activity.[5]

5.3 Parkinson's Disease

PD, named after the English surgeon Dr. James Parkinson who first described the disease as "shaking palsy," is the second most common neurological disorder of the CNS after AD. The clinical characterizations of the disease include resting tremor, bradykinesia, rigidity, and postural instability. It is estimated that about 3% of the total population above the age of 65 are afflicted with this disease. Globally, the disease affects about 5 million people with blacks in Africa having the lowest rates; higher prevalence rates have been reported for Asians in China and Japan; and the highest rate among Caucasians in Europe and North America, with 1 million patients in the United States alone.

Available evidence indicates that the pathology of PD is associated with the specific degeneration of dopaminergic neurons in *substantia nigra* along with substantial reduction in dopamine (DA) content in the striatum and other structures of the basal ganglia with the associated presence of Lewy bodies, ubiquitinated protein deposits in the neuronal cytoplasm. Studies have also implicated oxidative stress, mitochondrial dysfunction, and certain neurotoxins as possible causes of apoptosis in dopaminergic neurons of which oxidative stress is believed to play a major role in the pathogenesis of PD. With the availability of suitable animal models that mimic the human condition, the current therapeutic approach has been targeted at increasing the amount of DA by inhibiting monoamine

oxidase (MAO) (responsible for metabolizing DA to less active compounds) or elevating the concentration of the DA precursor levodopa (L-DOPA).[6] While this approach has ameliorated the symptoms of the disease, it has not provided an effective treatment or even the reversal of the neurological damage that causes PD.

It has been suggested that body weight alterations and eating habits in patients with PD, including those who underwent deep brain stimulation surgery, may be useful in the management of the disease. This is indicative of the possible role of diet in both the prevention and treatment of this disease. Natural products alongside conventional drugs have been suggested as possible effective treatments targeting multiple pathways. A review of potentially useful herbal compounds, crude plant extracts and fractions, semipurified compounds and plant-derived pure compounds, and herbal formulations has been published. It included extracts from crude plant parts/whole plants extracted in water or different organic solvents or semipurified fractions and natural compounds that include phytochemicals, either extracted from the plants or standard compounds. In this section, our interest is limited to those plants used in African traditional cuisine with clearly demonstrable activity against PD and some food plants that are used in traditional medicine for the treatment of PD. The most commonly used dietary plants from Africa for PD are the beans of *Mucuna pruriens* and *Vicia faba* for their L-DOPA content, and *Garcinia kola* seeds, *Moringa oleifera*, *Picralima nitida*, *Cola acuminata*, *Ocimum gratissimum*, *Carissa edulis*, *Agathosma betulina*, *Andrographis paniculata*, *Xylopia aethiopica*, *Vernonia amygdalina*, *Prunus africana*, and *Camellia sinensis* catechins for their antioxidant properties and/or neuroprotective properties.

5.3.1 Other Food Plants Used in Traditional Treatment of PD

Astragalus membranaceus (Fisch.) Bge.
Astragalus membranaceus (Fisch.)
Bacopa monnieri (Brahmi)
Camellia sinensis (L.) O. Kuntze
Cassia tora L.
Cassia obtusifolia L.
Centella asiatica
Chrysanthemum indicum L.
Cistanche deserticola
Cistanche phelypaea
Cistanche tubulosa
Citrus tangerine
Citrus aurantium
Citrus sinensis
Clausena lansium
Evolvulus alsinoides
Hypericum perforatum L.
Morus alba
Mucuna pruriens

Murraya koenigii L.
Nardostachys jatamansi
Ocimum gratissumum
Paeonia lactiflora Pall.
Plumbago scandens
Portulaca oleracea
Polygala tenuifolia Willd.
Polygonum cuspidatum
Psoralea corylifolia L.
Pueraria lobata (Willd.)
Pueraria thomsonii Benth
Rhodiola crenulata (Hook. f. et Thoms.)
Salvia miltiorrhiza Bge.
Scutellaria baicalensis Georgi
Sida acuta
Sida cordifolia
Trifolium pratense
Tripterygium wilfordii Hook F.
Uncaria rhynchophylla
Vaccinium cyanococcus (blueberries)
Valeriana officinalis
Vitis vinifera (grape vine)
Zingiber officinale

5.4 Sources of Antioxidants in Foods

The literature has shown that antioxidants occur widely throughout the plant kingdom but dietary antioxidants are generally obtained from phytochemicals found in dietary plants. Vegetables, fruits, and nuts in particular are very important for human health because they occur naturally as whole foods and are rich in antioxidants and a large variety of other nutrients. They are not only good sources of minerals but also contain vitamins, polyphenols, and pigments.[7] A large number of vegetables, such as amaranth, kale, spinach, bitter leaf, *Cleome gynandra*, broccoli, onions, carrots, eggplant, garden egg leaves, scent leaf (*Ocimum* spp.), and cucumber, are rich sources of antioxidants. Other sources include okra, tomatoes, green and black tea, virgin coconut oil, cocoa and dark chocolate, palm oil olein, black-eyed beans and other pulses, peppers, pomegranate, *Andrographis*, hog plum (*Spondias mombin* Linn.), bush mango (*Irvingia gabonensis* Baill.), monkey cola (*Cola millenii* K. Schum.), fenugreek seeds, soy, sorghum, kinkeliba tea (*Combretum micranthum*), African star apple (*Chrysophyllum albidum* G. Don.), bitter kola, rooibos tea, and polyphenol-rich dietary plants. New methodologies of extraction, purification, identification,

and quantification of antioxidants using ecofriendly techniques have been developed to improve the extraction yields while protecting the chemical integrity of the compounds.

Several analytical methods are available for the determination of antioxidant activity of natural products, which involve diverse instrumental techniques for the extraction, separation, identification, and quantification of these compounds. The antioxidant activity depends on a number of factors, including type of substrate, medium, and initiators; oxidation conditions, partitioning properties of the antioxidant between lipid and aqueous phases, and the experimental method used.[8] Table 5.2 summarizes the major methods employed in the evaluation of antioxidant substances. The quantification of antioxidants has been done using one or more of these methods: *in vivo* animal studies, *in vitro* electrochemical techniques, chemiluminescence, electron spin resonance, chromatography, capillary electrophoresis, nuclear magnetic resonance, near infrared spectroscopy, and mass spectrometry methods.[9] Since most antioxidants occur in their natural state, they are often unstable and some of them lose activity after processing.[10] Furthermore, it is not reliable to extrapolate the results from simple *in vitro* experiments to the heterogeneous conditions of multifaceted *in vivo* systems where the possible action on the target tissues is affected by absorption, distribution, metabolism, and excretion.[11] It is therefore recommended that whole food antioxidants should be used in preference to isolated compounds with questionable bioavailability.

TABLE 5.2

In Vitro Methods Usually Employed for Testing the Antioxidant Activity of Pure Compounds and Extracts

Antioxidant Activity Assay	Substrate/Initiator	Mechanism
TOSC (total oxidant scavenging capacity)	$ROO^{\cdot}$, $O_2^{\cdot}-$, $HO^{\cdot}$, HOCl, LO(O) , ONOO–, $^1O_2$	Scavenging, chain breaking
Liposome oxidation	$ROO^{\cdot}$, Fe^{2+}	Scavenging, chain breaking, chelating
βC (β-Carotene bleaching)	$ROO^{\cdot}$	Scavenging, chain breaking, competition method
CAT (conjugated autoxidizable triene)	$ROO^{\cdot}$	Chain breaking
Crocin bleaching	$ROO^{\cdot}$	Scavenging, chain breaking, competition method
FTC (antioxidant activity in the linoleic acid system with ferrothiocyanate reagent)	$ROO^{\cdot}$	Scavenging, chain breaking
Peroxyl radical scavenging	$ROO^{\cdot}$	Scavenging, chain breaking
TAR (total antioxidant reactivity)	$ROO^{\cdot}$	Scavenging, indirect competition method of chain
TRAP (total radical-trapping antioxidant parameter)	$ROO^{\cdot}$	Scavenging, chain breaking
ORAC (oxygen-radical absorbance capacity)	Oxygen radical, $ROO^{\cdot}$	Scavenging, chain breaking
Peroxynitrite scavenging	ONOO–	Scavenging, chain breaking
Photochem (photochemiluminescence)	$O_2^{\cdot}-$	Scavenging, chain breaking
SRS (superoxide radical scavenging)	$O_2^{\cdot}-$	Scavenging, chain breaking
PM (phosphomolybdenum method)	Mo^{6+}	Reducing capacity

(*Continued*)

TABLE 5.2 (*Continued*)

In Vitro Methods Usually Employed for Testing the Antioxidant Activity of Pure Compounds and Extracts

Antioxidant Activity Assay	Substrate/Initiator	Mechanism
TBARS (thiobarbituric acid-reacting substances)	LDL, $ROO^{\cdot}$	Adduct malondialdehyde–thiobarbituric acid (MDA–TBA) formation, scavenging, chain breaking
CD (conjugated dienes)	LDL	Oxidation by copper, aldehydes formation
In vitro LDL oxidizability	LDL	Oxidation by copper, conjugated dienes determination
Iodometric assay of lipid peroxides	LDL	Iodide oxidation by lipid peroxides
Hypochlorous acid scavenging	HOCl	Scavenging, chain breaking
Deoxyguanosine oxidation	$HO^{\cdot}$, H_2O_2, Fe^{2+}	Scavenging, chain breaking, chelating
Deoxyribose oxidation	$HO^{\cdot}$, H_2O_2, Fe^{2+}	Scavenging, chain breaking, chelating
HOSC (hydroxyl radical scavenging capacity)	$HO^{\cdot}$	Scavenging, chain breaking
HPS (hydrogen peroxide scavenging)	H_2O_2	Scavenging, chain breaking
Reduction of the Fremy's radical	*Fremy's* (potassium nitrosodisulfonate)	Scavenging, indirect competition method of chain lipid peroxidation (chain breaking)
FRAP (ferric-reducing antioxidant power)	Fe^{3+}-TPTZ	Reducing capacity, indirect competition method of chain lipid peroxidation (chain breaking)
RP (reducing power)	Fe^{3+}	Reducing capacity
FIC (ferrous ion-chelating assay)	Fe^{2+}, Cu^{2+}	Chelating
DPPH	$DPPH^{\cdot}$ (a,a-diphenyl-b-picrylhydrazyl)	Scavenging, decolorization assay, indirect competition method of chain lipid peroxidation (chain breaking)
DMDP	$DMDP^{\cdot+}$ (*N*,*N*-dimethyl-*p*-phenylenediamine)	Scavenging, decolorization assay, indirect competition method of chain lipid peroxidation (chain breaking)
CUPRAC (cupric ion reducing antioxidant activity)	Cu^{2+}	Reducing capacity
Trichloromethyl peroxyl scavenging	$CCl_3O_2^{\cdot}$	Scavenging
TRAA (a-tocopheroxyl radical attenuating ability)	a-Tocopheroxyl	Scavenging
ABTS or TEAC (Trolox equivalent antioxidant capacity)	$ABTS^{\cdot+}$ [2, 2'-azinobis (3-ethylbenzothiozoline-6-sulfonate)]	Scavenging, decolorization assay, indirect competition method of chain lipid peroxidation (chain breaking)

Source: Adapted from Conde, E. et al. 2010. *Separation, Extraction and Concentration Processes in the Food, Beverage and Nutraceutical Industries.* Woodhead Publishing Limited, London. Chapter 18, pp. 506–594.

Note: The activities considered include antiradical, anti-lipoperoxidation, metal chelation and reducing capacity.

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6

Effect of Phytonutrients on Chronic Inflammatory Diseases and Aging

6.1 Introduction

Inflammation is a normal but complex biological protective response induced by tissue injury or infection. It is a highly regulated first-line defense against foreign invaders, such as microorganisms, toxins, allergens, or other foreign xenobiotics. Inflammation is essential to generate both innate immunity, which is the first line of body defense acquired from birth (nonspecific, less diverse, no memory), and adaptive immunity, which is an adaptation of the immune system to respond to particular infectious agents. It also functions to remove dead or damaged tissue as well as initiate the body's healing and repair process. However, when inflammation is chronic and uncontrolled, it becomes detrimental to the tissues and dangerous to human health. The four cardinal signs of inflammation in its acute phase are redness, swelling, heat, and pain. The inflammatory process involves a general accumulation of extravascular plasma proteins, including proinflammatory cytokines and chemokines in addition to a variety of immune inflammatory cell types. Inflammation plays an important role in various diseases, such as rheumatoid arthritis, atherosclerosis, and asthma, all of which show a high prevalence globally. Chronic inflammation occurs when the negative regulatory mechanism appears to be dysfunctional. Studies have shown that during an inflammatory response, mediators, such as proinflammatory cytokines, including interleukin IL-1, tumor necrosis factor (TNF), interferon (INF)-α, IL-6, IL-12, IL-18, and the granulocyte–macrophage colony-stimulating factor, are released. The body usually regulates the proinflammatory response through a cascade of antagonism by anti-inflammatory cytokines, such as IL-4, IL-10, IL-13, IFN-α, and the transforming growth factor. The nuclear factor-κB (NF-κB), a transcription factor, also plays an important role in the inflammatory response by regulating the expression of various genes encoding pro-inflammatory cytokines, adhesion molecules, chemokines, growth factors, and inducible enzymes such as cyclooxygenase-2 (COX-2) and nitric oxide synthase (iNOS).[1]

Prevention and amelioration of chronic inflammation play a pivotal role in the maintenance of optimum health. Chronic inflammation results in the excess production and sustained release of several endochemicals such as eicosanoids, C-reactive protein (CRP), TNFα, NF-κB, interleukins, cyclooxygenases, and lipoxygenases.

The balance between pro- and anti-inflammatory agents can be distorted, which leads to persistent inflammation sometimes caused by even low levels of proinflammatory chemicals over a long time. The result is illness and certain diseases, including arthritis, cardiovascular diseases, cancer, diabetes, obesity, neurological diseases, pulmonary diseases, psychological diseases, and autoimmune diseases. Certain food plants are capable of

ameliorating the deleterious effects of chronic inflammation and some of them can block the initiation of the proinflammatory endochemicals in the first place. Ginger (especially the aged roots), bitter kola (*Garcinia kola*), turmeric, moringa, licorice, garlic, and basil are among the food substances with proven anti-inflammatory properties.

Another class of dietary plants that are worthy of consideration are those that are capable of countering platelet aggregation as they offer protection against thrombotic disorders. Platelets in blood have an active role in hemostasis during damage to blood vessels and thrombosis by forming compact and adhesive aggregates. Compounds found in many of the functional foods discussed in this section have shown evidence of significant inhibitory effect on platelet aggregation.

6.2 Chronic Noncommunicable Diseases

In the past, most health care resources and medical research in Africa have been directed mainly toward infectious diseases, especially malaria, zoonotic (animal borne) diseases, HIV-AIDS, and complications arising from poor nutrition and hygiene. However, recent trends in the disease pattern in the continent suggest that noncommunicable diseases (NCDs) have become a major cause of death in Africa. An alarming aspect of this phenomenon is that death due to NCDs, especially cardiovascular diseases, occurs at a much younger age in Africa than in developed or industrialized countries. It has been observed that cardiac failure is becoming common in sub-Saharan Africa and the onset of acute heart failure takes place two decades earlier than in Western countries.[2] The projections for 2020 are that cardiovascular disease and chronic noninfective disease will account for 60% of morbidity and 65% of mortality in that region.[3] It is further predicted that chronic NCD, in particular, cardiovascular disease, will be the major cause of mortality and morbidity, amounting to four times that of infective disease, by 2020.[4] Many reasons have been brought forward to explain the surge in the incidence of and the mortality caused by NCDs in Africa but a major consideration has been the shift in the dietary habits of Africans, especially the urban rich. Current findings indicate that epigenetic modifications related to globalization may crucially contribute to explain current and future patterns of NCDs, and thus deserve attention from environmental researchers, public health experts, policy makers, and concerned citizens.[5]

The major NCDs are outlined in Table 6.1. The most common ones include diabetes, obesity, immune system disorders, neurological diseases, cardiovascular diseases, hypertension, atherosclerosis, respiratory disorders, musculoskeletal disorders, and gastrointestinal disorders. Cancers are not included because of the multisystem involvement and accordingly a separate chapter has been devoted in this book to functional foods with anticancer properties.

6.3 Anti-Inflammatory Properties of Culinary Herbs and Spices

The International Standards Organization (ISO) defines spices and condiments as "vegetable products or mixtures thereof, free from extraneous matter, used for flavoring, seasoning

TABLE 6.1

Noncommunicable Diseases

Central Nervous System
Alzheimer's disease
Attention deficit hyperactivity disorder
Bipolar mood disorder
Chronic fatigue syndrome
Dementia
Depression
Epilepsy
Generalized anxiety disorder
Migraine
Multiple sclerosis
Parkinson's disease
Schizophrenia
Stroke
Cardiovascular System
Angina
Cardiac arrhythmias
Coronary artery disease
Endocarditis
Heart failure and cardiomyopathy
Hyperlipidemia
Hypertension
Peripheral vascular disease
Blood or Hematological
Anemia
Cryoglobulinemia
Deep vein thrombosis
Hemophilia
Thalassemia
Thromboangiitis obliterans
Thrombocytopenia
Wegener's granulomatosis
Respiratory System
Asthma
Bronchiectasis
Chronic obstructive airways disease
Cystic fibrosis
Pulmonary tuberculosis
Endocrine System
Addison's disease
Congenital adrenal hyperplasia
Cushing's syndrome
Diabetes mellitus
Diabetes insipidus
Hypoparathyroidism

(*Continued*)

TABLE 6.1 (*Continued*)

Noncommunicable Diseases
Pheochromocytoma
Pituitary adenomas
Polycystic ovarian syndrome
Thyroid disorder
Musculoskeletal System
Ankylosing spondylitis
Dystonia
Gout/hyperuricemia
Motor neuron disease
Myasthenia gravis
Rheumatoid arthritis/osteoarthritis/osteoporosis
Paget's disease
Paraplegia
Sjogren's disease
Systemic lupus erythematosus
Ear, Nose, and Throat
Allergic rhinitis
Tonsillitis
Adenoiditis
Chronic serous otitis media
Gastrointestinal system
Chronic cholecystitis/chronic pancreatitis
Cirrhosis
Gastroesophageal
Reflux disorder
Hemorrhoids
Hepatitis
Inflammatory bowel disease (Crohn's disease, ulcerative colitis)
Skin
Dermatomyositis
Psoriasis
Pemiphigus
Scleroderma
Eye
Dry eye syndrome
Glaucoma
Genitourinary System
Benign prostate hypertrophy
Chronic renal failure
Chronic pyelonephritis
Immune System
Allergies
DiGeorge syndrome

and imparting aroma to foods." The term "spice" is often used to include "herbs" but there is a technical distinction between herbs and spices. Herbs may be defined as the dried leaves of aromatic plants used to impart flavor and odor to foods. The leaves are commonly traded separately from the plant stems and leaf stalks. Spices, on the other hand, may be defined as the dried parts of aromatic plants with the exception of the leaves. This definition is wide-ranging and covers virtually all parts of the plant.[6]

It is now established that transcription factors and signaling molecules regulate the inflammatory cascade and that most chronic diseases are caused by dysregulation of inflammatory pathways, leading in turn to chronic inflammation. Identification of such molecular targets has led to the discovery that many herbs and spices used as part of African cuisine possess anti-inflammatory properties as evidenced by *in vitro* and *in vivo* effects, as well as clinical reports. These include ginger, turmeric, alligator pepper, onions, scent leaves, sage, cocoa, red and black peppers, and carrots. The classes of compounds responsible for the biological activities of these anti-inflammatory foods cover a very wide range, including (i) aromatic acids, (ii) polyphenols, (iii) alkaloids, (iv) terpenoids, (v) amino acids and peptides, and (vi) organosulfides (see Figure 6.1). The anti-inflammatory functional foods that contain many bioactive molecules are more suitable for the management of chronic diseases than pharmaceutical-based agents by being active on multiple molecular targets, since it is well known that chronic diseases are caused by dysregulation of multiple genes and many modern medicines are based on the modulation of a single target and therefore are less likely to be as effective.

The observed anti-inflammatory health benefits of phytochemicals have been attributed to the following mechanisms of action: (1) direct antioxidant activity or increase in the expression of antioxidant proteins; (2) attenuation of endoplasmic reticulum stress signaling; (3) blockade of proinflammatory cytokines; (4) blockade of transcription factors related to metabolic diseases; (5) induction of metabolic gene expression, and (6) activation of transcription factors that antagonize inflammation.[7]

6.3.1 Aromatic Acids

These are compounds with single phenol rings and carboxylic acids found mainly as components of essential oils. They are also present in pigmented fruits and nuts. They contribute to the anti-inflammatory activities found in ginger, lemongrass, eucalyptus, clove, sage, and scent leaves (*Ocimum* spp.) They are usually water soluble and because of their structure are prone to bio-conjugation and may not be readily bio-available. Caffeic acids, curcumin, and cinnamic acid are good examples. Salicylic acid obtained from willow bark is a well-known anti-inflammatory compound and the precursor of aspirin, acetylsalicylic acid. The widely occurring compound, ellagic acid, is a member of this group and acts predominantly as an antioxidant, which has applications to atherosclerosis since it reduces LDL oxidation. Related to the aromatic acids are the aromatic alcohols, aldehydes, and their condensation products found in green leafy vegetables.

6.3.2 Polyphenols

Polyphenols consist of large multiple aromatic chemical rings with OH groups and are perhaps the most ubiquitous class of compounds with significant anti-inflammatory activity. They occur in fruits and vegetables. These include compounds belonging to the following structural classes: coumarins, biflavonoids, anthocyanins, tannins, flavonoids and isoflavonoids, lignans, and phenylpropanoids.

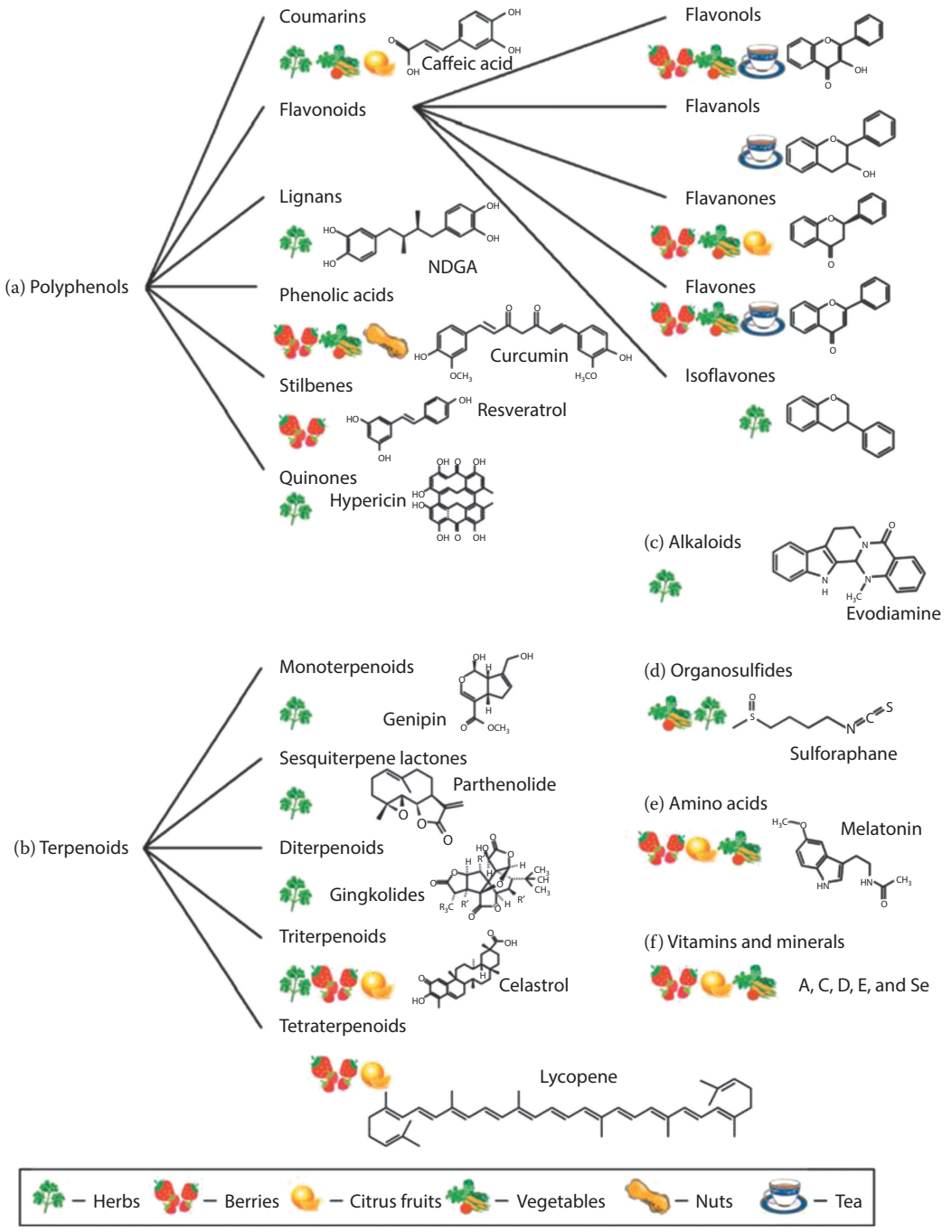


FIGURE 6.1
Bioactive compounds found in common food sources. Each chemical category is depicted with an example and linked to potential dietary sources. (After Prabhala, H. K., Pai, C., and Prabhala, R. H. 2013. Anti-inflammatory natural foods. In: R. R. Watson and V. Preedy (Eds.) *Bioactive Food as Dietary Interventions for Arthritis and Related Inflammatory Diseases*. Academic Press, London. Chapter 21, pp. 279–303.)

6.3.3 Stilbenes

Stilbenes are a small group of phenylpropanoids characterized by a 1,2-diphenylethylene moiety. The most notable stilbene is resveratrol, which is found in grapes, dark berries, and wine. Stilbenes are structurally related to diphenylethylene. Resveratrol and related compounds have been isolated from leaves of *Gnetum africanum*, *Combretum micrathum*, and *Gongronema latifolium*. The compound has been shown to be a potent inhibitor of COX-2 and other proinflammatory agents. Stilbenes have also been isolated along with tannins from the bioactive extract of Kakadu plum (*Terminalia ferdinandiana*) fruit and the extract showed activity against reference and clinical strains of *Proteus mirabilis* and *Proteus vulgaris*, believed to be possible bacterial triggers of rheumatoid arthritis.[9] Related to the stilbenes are the phenylpropanoids called lignans. Several plant species belonging to the families Asteraceae, Acanthaceae, Oleaceae, Apocynaceae, Lauraceae, and Myristicaceae are also sources of lignan-type compounds. Many lignans found in African medicinal plants exhibit antioxidant, antitumor, estrogenic, antimicrobial, and cholesterol-lowering activities.

6.3.4 Terpenoids

The terpenoids consist of a large class of molecules that are characterized by five-carbon units of isoprene (C_5H_8). They differ from simple terpenes by the presence of oxygen in their primary lipophilic hydrocarbon structure. The terpenoids are classified according to the number of isoprene units they contain into mono- (one), sesqui- (one and half), di- (two), tri- (three), and tetra- (four) terpenoids. Monoterpenoids are elaborated by many volatile oil-bearing plants such as *Eucalyptus*, *Ocimum*, ginger, lemongrass, peppers, etc. Diterpenes are found in alligator pepper, *Ocimum*, guinea pepper, and turmeric. The pronounced anti-inflammatory properties of African potato (*Hypoxis* spp., family Hypoxidaceae) are partly due to the presence of the triterpenes, β-sitosterol, stigmasterol, and stigmastanol.[10]

6.3.5 Alkaloids

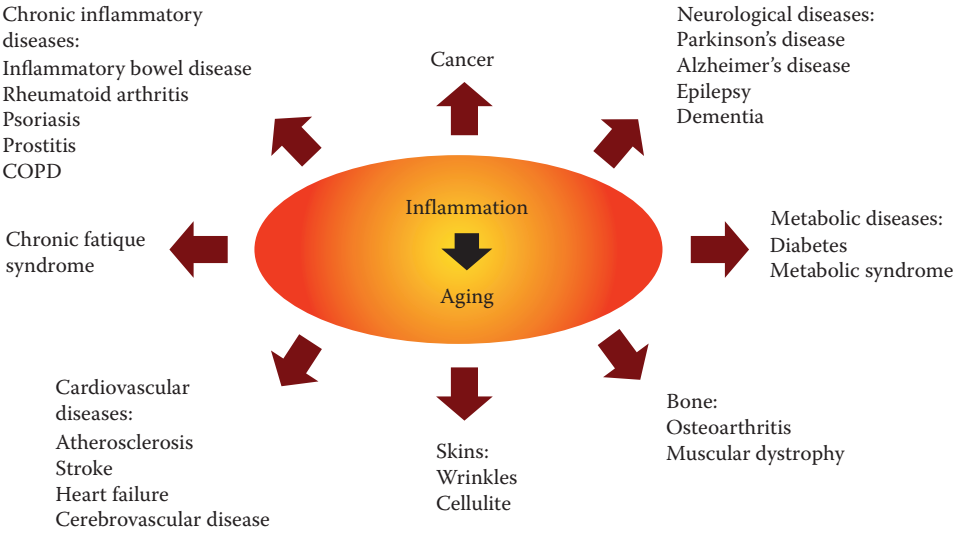
Alkaloids are a complex class of basic compounds often characterized by the presence of nitrogen in a heterocyclic ring. The anti-inflammatory activity of black pepper is attributed to the alkaloid piperine. Rutaecarpine and berberine are other examples of anti-inflammatory alkaloids that occur in functional foods. These compounds are often specific to the herbal remedies from which they are isolated and are generally diverse in their pharmacological activity. Steroidal alkaloids found in some plants belonging to the family Solanaceae (garden eggs) are responsible for the anti-inflammatory activities of such plants. Alkaloids possess very strong pharmacological activities and are more suited for development into pharmaceutical agents.

6.4 Inflammation and Aging

Globally, human life expectancy has continuously increased with more people than ever before attaining the biblical three score and ten (70) years. It is projected that by 2025, 10.4%, 18.8%, and 21% of the world, the U.S., and European populations, respectively, will have persons aged 65 years and older.[11] This is a major point of concern for public health, since older ages are associated with an increase of the above-mentioned chronic degenerative

disorders (Table 6.1) and an increase in the need for medical attention and social support with significant effects on social and economic programs. Aging is an intrinsic process that commences in the fetus and advances throughout our entire life. The onset of the aging process is characterized by a gradual but relentless impairment of normal physiological functions and the concomitant lack of ability to resist stresses with the higher risk of morbidity and mortality.[12] There are many theories as to why and how we age. Conceptually, they range from aging as a result of a gene-based "program" of self-destruction, to aging and decline as the result of a purely random sequence of damaging events within cells. Although the origin and the dynamics of the aging process is not well understood, it is believed that interacting oxidative stress, systemic low-grade chronic inflammation, and the impairment of hormonal, fibrinolytic, and immunological status are major risk factors underlying aging and age-related diseases such as osteoarthritis, cancer, type 2 diabetes, AD, cognitive decline, obesity, osteoporosis, metabolic syndrome, cardiovascular and cerebrovascular diseases, and other NCDs.[13] Chronic inflammatory processes also appear to drive the progression of these deleterious age-related changes that lead to physiological decline, dysfunction, disease, and death.

In Africa, the impact of infectious diseases on the health status, morbidity, and mortality in the continent has greatly overshadowed the enormous role the African diet has played in the sustenance and optimization of health. A diet regimen that could enable Africans to withstand such a heavy microbial burden is worthy of closer study. As discussed in the earlier chapters of this book, African societies are increasingly abandoning the protective vegetable-based indigenous diet for the high-fat overprocessed food of Western cuisine, with obvious consequences on health, morbidity, and mortality. A comparative study in Congo showed clearly that living in urban areas where people are likely to eat more Western-type foods is a major risk factor (among others) to explain the significantly higher incidence of type 2 diabetes among elderly people living in the city when compared to their rural counterparts.[14] The examples listed in Table 6.2 are merely illustrative of the rich cuisine available in the continent for the amelioration of inflammation-induced diseases in geriatric care.



Aging-associated chronic diseases regulated by inflammation. (Adapted from Prasad, S., Sung, B., and Aggarwal, B.B. 2012. *Prev. Med.*, 54[Suppl]: S29–S37.)

TABLE 6.2

Food Plants with Anti-Inflammatory Activities and Potential Effect on NCD

Plant Species	Part Used
Abelmoschus esculentus	Fruits
Adansonia digitate	Fruits
Aframomum melegueta	Seeds
Allium cepa L.	Bulbs, rhizome
Allium sativum	Bulbs, rhizome
Ananas comosus	Fruits
Anona muricata	Fruits
Artocarpus heterophyllus	Fruits, seeds
Aspalathus linearis	Leaves
Balanitas aegyptiaca Del.	Fruits
Bulbine frutescens (L.) Willd.	Leaves
Cajanus cajan	Seeds
Capsicum frutescens L.	Fruits
Cocos nucifera	Nuts, fruit, oil
Commelina nudiflora	Leaves
Costus afar	Aerial parts
Garcinia kola	Seeds, fruit rind
Cleome gynandra L.	Leaves
Hibiscus sabdariffa	Calyx
Hypoxis hemerocallidea	Tubers
Ipomoea pes-capreae	Leaves
Moringa oleifera	Leaves, seeds, oil
Ocimum basilicurn	Leaves
Ocimum gratissimum	Leaves
Palisota hirsute	Aerial parts
Piper guineense	Fruits
Schwenkia americana	Leaves
Securidaca longipedunculata	Aerial parts
Solenostemon rotundifolius	Leaves, tubers
Sorghum bicolor	Seeds, leaves
Telfairia occidentalis	Seeds, fruit pulp
Terminalia ivorensis	Fruits, leaves
Tetrapleura tetraptera	Fruits
Theobroma cacao	Seeds, pod
Vernonia amygdalina	Leaves
Vigna unguiculata	Beans
Withania sominifera	Leaves
Zingiber officinale	Rhizome

6.4.1 Epigenetic Considerations in Aging

Epigenetics refers to heritable changes in phenotype (i.e., gene expression) without a change in the primary DNA sequence. Epigenetic mechanisms, namely, DNA methylation, histone modifications, and regulatory RNA-mediated gene silencing (noncoding RNA) synergize to sculpt chromatin structure and tune gene expression and therefore

are essential for normal development and differentiation of cells. Consequently, epigenetic alterations are associated with the onset and development of several chronic NCDs. It is therefore used to describe the possible interaction between genes and their surroundings (lifestyles, diets, and environmental effects) to produce a phenotype, and also to explain the mechanism of the structural adaptation of chromosomal regions so as to register, signal, or perpetuate altered activity states. Epigenetics, therefore, covers the study of mechanisms that control changes in heritable gene expression without altering the DNA sequence. Studies have shown that diet is a critical factor for provoking epigenetic changes during aging. It has also been observed that all of the epigenetic changes that occur during aging might affect, among other things, the immune system, leading to inflammatory processes that have consequences for health as discussed in the preceding section. Interestingly, the effect of diet on epigenetics occurs over a lifetime and much of that is initiated in the womb and during the early period of life. The hypothesis of the fetal origin of disease is thus based on studies showing that the fetal environment can cause changes to the epigenome that have long-term consequences for gene regulation and age-related diseases.[15] Studies have shown that mammalian embryos have evolved to adjust their organ and tissue development in response to an atypical environment. This adaptation, called phenotypic plasticity, allows the organism to thrive in the anticipated environment in which the fetus will emerge. It has been proposed that if the environment in which the fetus emerges differs from that in which it develops, phenotypic plasticity may provide an underlying mechanism for disease.[16] Epidemiological studies have shown that humans born small or large for gestational age have a higher likelihood of developing obesity as adults. The amount and quality of food that the mother consumes during gestation influences birth weight, and therefore the susceptibility of progeny to disease in later life. As laboratory studies have shown, restriction of nutrients or consumption of a high-fat diet during gestation may promote obesity in progeny by altering hypothalamic neuropeptide production and thereby increasing hyperphagia in offspring. In addition to changes in food intake, these animals may also direct energy from muscle toward storage in adipose tissue. It was also noted that generational inheritance studies in rodents further indicated that effects on body length, body weight, and glucose tolerance appear to be propagated to subsequent generations.[17] These observations have immense implications for adult health,[18] especially in Africa where most of the support for maternal health care are usually for the short term and thereby set up the population for unusually high levels of chronic NCDs later in life.

Epigenetic modifications were previously thought to be fixed during development and maintained over the lifetime. It has now been established that since abnormal epigenetic patterns (epimutations) can be induced during aging by various processes and no selective pressure regulates these epimutations, it is possible for hazardous, late-acting epigenetic patterns to exist and form the basis for development of many age-related disorders.[19] Fortunately, certain phytochemicals found in edible foods have been shown to be able to positively influence the body's response to these epigenetic modulators (Table 6.3). The effects of these modulators are more pronounced during the early stages of life. As shown in below, epigenetic modification at conception or in stem cells are likely to produce several fold more epimutations of different tissues and organs than modifications at later stages in life. Schumacher[19] has shown that neuronal epigenetic drift that occurs early in life may lead to age-dependent neurodegenerative disorders, such as AD or PD, at old age. He further argued that the relatively high frequency of *de novo* epimutations suggests that epigenetic alterations accumulate during aging. Small epimutations may be tolerated by the cells; however, once epigenetic deregulation reaches a critical

TABLE 6.3

Functional Foods and Their Constituents That Act as Epigenetic Modulators

Food Source	Compound	Class	Potential Epigenetic Target
Allium family	Allicin Diallyl disulfide Diallyl trisulfide *S*-allyl mercaptocysteine *S*-allylcysteine	Thiosulfonate	Histone modifications, miRNA
Alpinia officinarum, Alpinia galangal	Galangin	Polyphenol	DNA methylation
Apples, tea, onions, nuts, berries	Quercetin	Polyphenol	DNA methylation, histone modifications, miRNA
Apples	Phloretin (dihydrochalcone)	Polyphenol	DNA methylation
Apples, nuts, onions	Kaempferol	Polyphenol	Histone modifications
Basil	Ursolic acid	Terpenoid	Histone modifications, miRNA
Bitter melon	MCP30	Protein	Histone modifications
Black tea	Theaflavin 3,3′-digallate, ECCG	Polyphenol	miRNA, DNA methylation
Cashew nuts	Anacardic acid	Polyphenol	Histone modifications
Celery, parsley	Luteolin	Polyphenol	DNA methylation
Citrus	Hesperidin	Polyphenol	DNA methylation
Citrus	Naringenin	Polyphenol	DNA methylation
Cocoa beans, tea	Theophylline Flavonoids, anthocyanins	Terpenoid Polyphenols	Histone modifications DNA methylation
Coffee	Caffeic acid Chlorogenic acid	Polyphenol	DNA methylation
Cruciferous vegetables	Indole-3-carbinol	Glucosinolate	Histone modifications, miRNA
Cruciferous vegetables	Phenethyl isothiocyanate	Glucosinate	DNA methylation, histone modifications, miRNA
Cruciferous vegetables	Sulforaphane	Glucosinate	DNA methylation, histone modifications, miRNA
Curry tree	Mahanine	Alkaloid	DNA methylation
Dracaena, pomegranates	Delphinidin	Polyphenol	Histone modifications
Numerous fruits and vegetables	Ellagic acid	Polyphenol	Histone modifications
Garcinia spp.	Clusianone Garcinol Guttiferone A Guttiferone E	Polyisoprenylated benzophenone	Histone modifications, miRNA
Ginger	6-methoxy-2E,9E-humuladien-8-one	Sesquiterpene	Histone modifications
Grapes	Piceatannol Resveratrol	Polyphenol	DNA methylation, histone modifications, miRNA

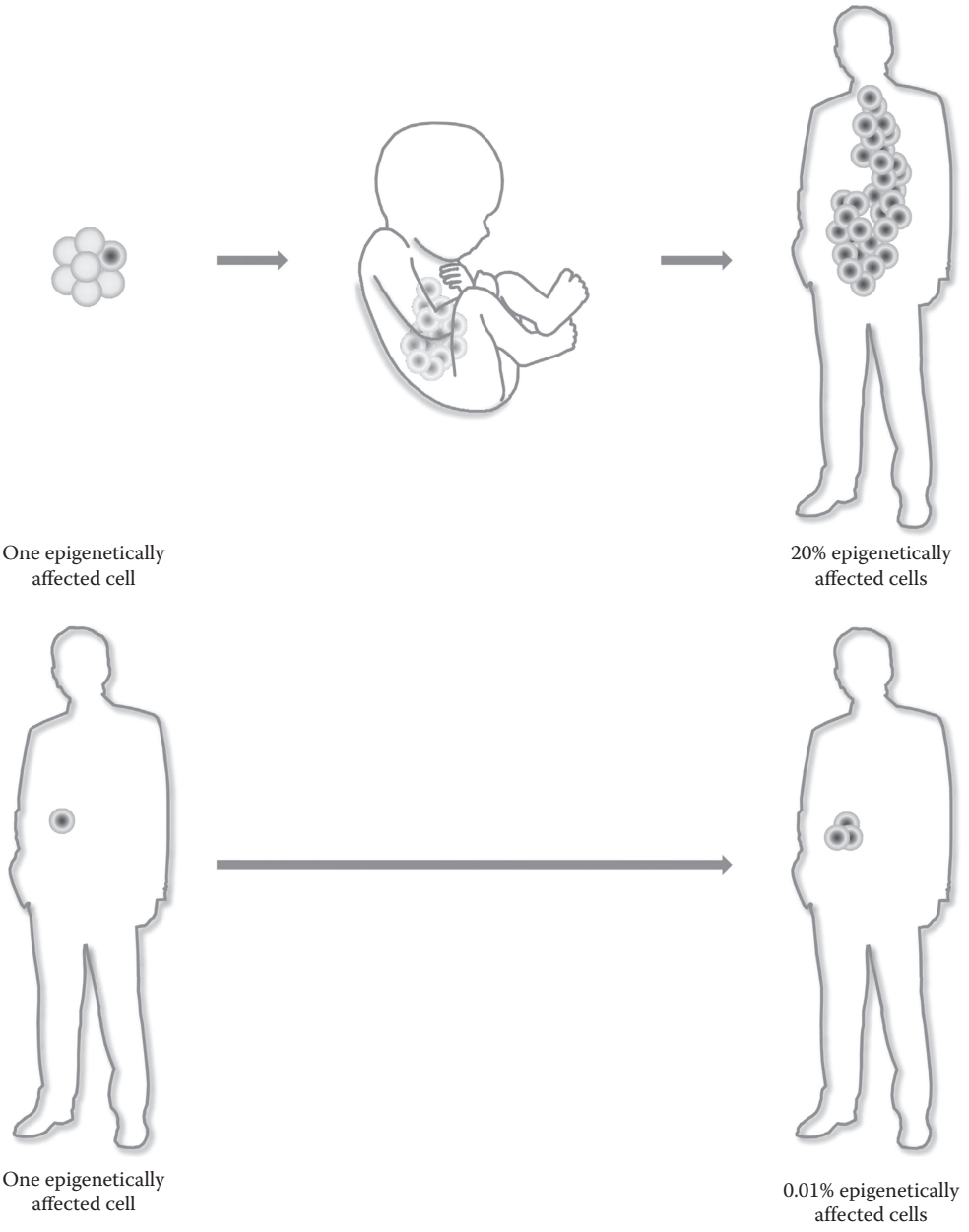
(*Continued*)

TABLE 6.3 (*Continued*)

Functional Foods and Their Constituents That Act as Epigenetic Modulators

Food Source	Compound	Class	Potential Epigenetic Target
Green tea	Catechin/epicatechin EGCG Epicatechin gallate Epigallocatechin	Polyphenol	DNA methylation, histone modifications, miRNA
Licorice	Isoliquiritigenin	Polyphenol	Histone modifications, miRNA
Mandarin	Flavone	Polyphenol	Histone modifications
Mangoes, blackberries	Gallic acid	Polyphenol	Histone modifications
Nigella sativa	Thymoquinone	Terpenoid	Histone modifications
Olives	Protocatechuic acid	Polyphenol	DNA methylation
Onions, garlic	Allylisothiocyanate	Glucosinate	Histone modifications, miRNA
Pigment found in many red fruits, vegetables, berries	Cyanidins	Anthocyanins	DNA methylation
Rapeseed	Sinapic acid	Polyphenol	DNA methylation, histone modifications
Rhubarb	Emodin	Polyphenol	Histone modifications, miRNA
Rosemary	Rosmarinic acid	Polyphenol	DNA methylation
Soy	Biochanin A Daidzein Genistein	Polyphenol	DNA methylation, miRNA, histone modifications
Strawberries	Fisetin	Polyphenol	DNA methylation, histone modifications, miRNA
Tomatoes	Lycopene	Carotenoid	DNA methylation
Turmeric	Curcumin	Polyphenol	DNA methylation, histone modifications, miRNA
Walnuts and various berries, fruits, vegetables	Myricetin	Polyphenol	DNA methylation

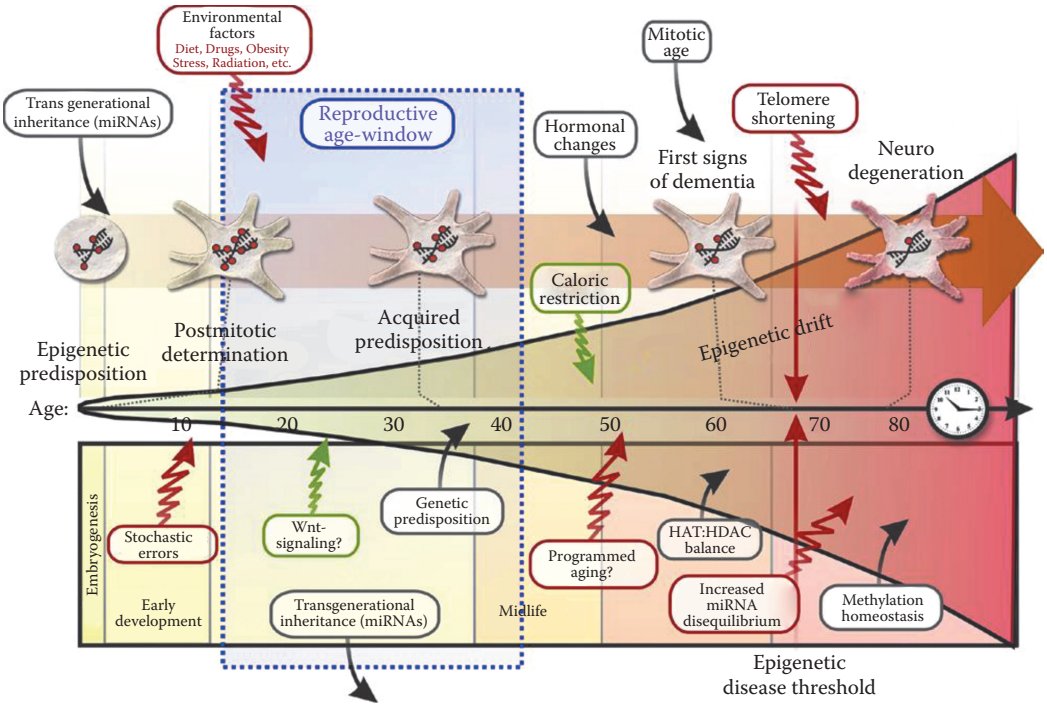
threshold, the cells no longer function properly. The phenotypic outcome depends on the overall effect of a series of pre- and postnatal impacts on the pre-epimutation. However, only some predisposed individuals will reach the "threshold" of epigenetic deregulation that causes the phenotypic changes that meet the diagnostic criteria for a clinical disorder. Epigenetic drift may not only be affected by several internal and external factors—some individuals may already be epigenetically predisposed at birth, due to transgenerational epigenetic effects. Transgenerational epigenetic inheritance results either from incomplete erasure of parental epigenetic marks during phases of epigenetic reprogramming at fertilization, or may be established by small RNA species that pass through the germline. Since all organisms eventually die from different causes, epigenetic patterns beneficial in early life are favored by natural selection over patterns advantageous later in life.



Epigenetically affected cells after interaction with dietary active components. (From Urdinguio, R. et al. 2014. Epigenetics, inflammation, and aging. In: *Inflammation, Advancing Age and Nutrition*. Chapter 8, pp. 85–101. With permission.)

When such interaction occurs during early development, the affected cell or cells will divide and give rise to many epigenetically modified tissues and organs. Supposing that one stem cell has suffered an epigenetic change due to maternal diet, the modification to epigenetic patterns will be inherited by all its descendant cells in the embryo and, later, in the mature organism. On the other hand, if the modification occurs when the organism

has completely developed, that is, is an adult, the epigenetic modification derived from a specific diet compound would affect only a restricted number of cells, given that adult stem cells have limited pluripotency, and thus the modification would have only a local effect.



Age-dependent epigenetic drift. (Reprinted from *Handbook of Epigenetics: The New Molecular and Medical Genetics*., Schumacher, A., Aging epigenetics, Chapter 25, pp. 405–422, Copyright 2011, with permission from Elsevier.)

Shown here is the example of neuronal epigenetic drift that may lead to age-dependent neurodegenerative disorders, such as AD or PD. The relatively high frequency of *de novo* epimutations suggests that epigenetic alterations accumulate during aging. Small epimutations may be tolerated by the cells; however, once the epigenetic deregulation reaches a critical threshold, the cells no longer function properly. The phenotypic outcome depends on the overall effect of a series of pre- and postnatal impacts on the pre-epimutation. Only some predisposed individuals will reach the "threshold" of epigenetic deregulation that causes the phenotypic changes that meet the diagnostic criteria for a clinical disorder. Epigenetic drift may not only be affected by several internal and external factors—some individuals may already be epigenetically predisposed at birth due to transgenerational epigenetic effects. Transgenerational epigenetic inheritance results either from incomplete erasure of parental epigenetic marks during phases of epigenetic reprogramming at fertilization or may be established by small RNA species that pass through the germline. Since all organisms eventually die from different causes, epigenetic patterns beneficial in early life are favored by natural selection over patterns advantageous later in life. Deleterious epigenetic drift occurring after the reproductive phase is relatively neutral to selection, because its bearers have already transmitted their genes (and potentially epigenetic information) to the next generation.

6.4.2 Andropause and Aging

Andropause, a prevalent pathology of men, which results from an imbalance in steroid hormone concentrations, is often associated with aging, and reduces the quality of life of the sufferer. Although not regarded by medicine as a disease or recognized by the World Health Organization as an illness that requires therapy, andropause affects a high percentage of men above 50 years of age. It is reported that andropause affects about 20% of males over 40 years of age. At the age of 80 years and above, more than 50% of men have various degrees of andropause.[21] It is estimated that between 3 and 5 million males in the United States are andropausal.[22] Andropause, also referred to as late-onset hypogonadism (LOH) in males,[23] partial androgen deficiency of aging males (PADAM), or menopause of males, results from an imbalance in the concentrations of the steroid hormones, testosterone and estradiol.[24] Men undergo these hormonal alterations with age and this is worrisome as low testosterone levels are associated with pathologies such as diabetes, reduced bone and muscle mass, impotence and impaired sexual function, depression, lethargy, and decreased quality of life.[25] This process is believed to be quite insidious, beginning gradually, and over time results in both physiological and psychological changes. In most men undergoing andropause, the hormonal changes are either an increase in the level of estradiol or a decrease in the level of testosterone, or both, a condition similar to the effect of biochemical castration, such that serum total, free, or bioavailable testosterone levels drop markedly.

Several studies have shown that exogenous estrogen administration, especially from persistent environmental pollutants, can result in unintended biochemical castration of males. The Leydig cells of the testes are known to produce testosterone as a result of stimulation by luteinizing hormone, a pituitary hormone. Dormancy of the testes results from a sustained inhibition of pituitary function, such that the testes atrophy. The production of biochemical castration is a known indirect effect of estrogen.[26] In laboratory experiments, the administration of estradiol valerate in combination with DHT led to biochemical castration in rats and mimicked the situation observed in andropause, while maintaining serum concentrations of the reduced equivalent of testosterone, DHT, so as to sustain basic physiological processes that require androgens, such as the maintenance of the heart beat.

The treatment of andropause in conventional medicine consists mainly of testosterone replacement therapy, which sometimes poses serious adverse effects.[27] Certain African food plants have been shown to be capable of preventing or delaying the onset of andropause. They include seeds of the fluted pumpkin (*Telfairia occidentalis*), yellow yam (*Diocorea dumetorum*), bitter kola (*Garcinia kola*), fermented cocoa pod (*Theobroma cacao*), locust bean (*Parkia biglobosa*), eru (*Gnetum africanum*), gongronema (*Marsdenia latifolia*), and velvet bean (*Mucuna pruriens*). The fluted pumpkin has shown to be effective in laboratory studies in the regeneration of testicular damage and also to increase spermatogenesis in animals.[28] In another study, it was found that a diet containing 15% seeds showed inhibition of the induction of experimental andropause.[29] The test diet containing fluted pumpkin seeds resulted in a modest reduction of biochemical castration and an improvement in the secretory capacity of the testes of the test rats, relative to the control group that received the hormones but was placed on a normal diet. *T. occidentalis* seeds incorporated into the diet may be useful in inhibiting the induction of andropause in humans and therefore useful in the management of aging complications.

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7

Digestive System Dysfunction: Dietary Interventions

7.1 Introduction

The gastrointestinal system occupies a pivotal position in the conceptual framework of African traditional medicine; the gut is considered a very important aspect of the human health and disease cycle. Gastrointestinal diseases are common in most African communities and these are attributable to a number of ecological and cultural variables inherent in rural Africa. Among the diverse symptoms and diseases that have been recorded among these communities are colic, dyspepsia, nausea, hemorrhoids, hepato- and splenomegaly, as well as intestinal worm infections, hematuria, diarrhea, and dysentery. Most rural or traditional African habitats are in territories that are characterized by high mean annual temperatures ranging between 20°C and 43°C; extremes in atmospheric humidity, exceeding 90% during the rainy season; reliance on rainfall or (sometimes contaminated) well water that is in limited supply and not ordinarily boiled for drinking; the use of hands in eating instead of cutlery; lack of refrigeration and other modes of food preservation, aside from air-drying; use of communal cooking and eating vessels; close proximity to livestock; earth-floored habitation units; high population density; minimal or no foot covering; exposure to human excreta; and no physical isolation of sick individuals, which exposes the communities to various gastrointestinal diseases.[1] Herbs used for the treatment of the so-called bowel and stomach diseases constitute about a third of remedies dispensed by traditional healers.

A healthy gut is associated with good health and a sick gut is in fact symptomatic diagnosis of many illnesses. It is considered important in traditional African medicine to ascertain whether a patient has a regular bowel movement at least once a day. The physical characteristics of the patient's stool are also considered important in order to establish the level of putrefaction of the fecal matter in the colon. If the patient is found to be constipated, it is regarded as an extremely serious ailment that must be addressed before any other medication or treatment is administered. Purgatives and laxatives are therefore considered important in traditional African medicine. The seriousness attached to the health of the gastrointestinal tract (GIT) explains the reasoning behind the many plants used in traditional medicine for the treatment of stomach-related diseases.

The human GIT is a complex organ that extends from the mouth to the anus, and includes the esophagus, stomach, approximately 13 feet of small intestine, and 7 feet of large intestine. It has a surface area suggested to be approximately 7000–8000 m^2, which is equivalent to the size of a soccer field. The GIT has a crucial role in survival, as it is responsible for breaking down food, extracting nutrients, exchanging fluids, and expelling waste. It is a dynamic organ that actively moves contents through the tract using coordinated ripple-type muscle contractions. As was indicated earlier, the gut operates like an assembly line

in reverse, and it works efficiently only when the delivery of material to the next stage is coordinated closely with the optimum rate of process at that stage. It also initiates the emptying of nutrients that are not required for normal body function. After processing food, the body extracts or assimilates nutrients that it needs and since it has no method of safely storing the food materials that have been "digested" but not absorbed, it requires that the assembly line should evacuate the wastes in order to make room for new food materials, to avoid poisoning the body tissues, and to not contaminate the fresh materials to be ingested. In people with constipation, food is retained in the colon for an extended period of time; it begins to putrefy, releases toxins that are harmful to the body, and eventually leads to "auto-intoxication." In such a closed and warm environment, bacterial and fungal growth is common, which in turn leads to the production of even more toxic substances that have a negative effect on many parts of the body. From an African perspective, the maintenance of a healthy gut is therefore fundamental in keeping healthy and that is why seemingly nonnutritious ingredients are included in the diet simply to ensure gastrointestinal health.

The colon can also be likened to a sewerage system, which when kept clean runs well and empties in a timely manner and does not pose any health threat. But when this sewerage system is allowed to stagnate and the refuse in it is allowed to decay, it becomes a cesspool. It is the danger of self-poisoning by the prolonged presence of toxic waste produced by decayed or rotten food substance in the colon that makes constipation a very serious condition. The fact that much of the biotoxins released by the decayed matter is taken up into the bloodstream and distributed throughout the body poses enormous danger to all the organs of the body.

These toxins from putrefied or decayed food residue could over time poison many organs in the body, including the heart, lungs, digestive system itself, skin, brain, and nervous system. In this cascade process, bad feeding leads to constipation, the blockage of the colon causes auto-intoxication, and the release of such toxins in turn gives rise to numerous diseases. The earlier statement that "you are what you eat" should be modified to "you are what you eat and do not excrete." This will be a better reflection of the influence of diet on human well-being because not all of the nutrients consumed in meals can be absorbed and utilized in the body (i.e., not all nutrients in diet matrices are "bioavailable") due to the various interactions that operate in the digestive system. Some substances called "antinutrients" occur in many staple plant foods, which inhibit the bioavailability of nutrients and can drastically reduce the amount of a nutrient that is absorbable from a meal. The unabsorbed nutrients and their partly digested derivatives should be removed from the body to allow for the consumption and absorption of fresher nutrients.

It is of utmost importance to ensure that there is bowel movement at least once or twice a day. A person whose bowel moves less than once a day should be considered as constipated. As the food matter stays in the colon for longer than necessary for nutrient absorption, it becomes even more compacted by the reabsorption of water from the food residue. The resultant so-called "well-formed stool" is actually certain evidence that the individual is constipated. Normal stool on the other hand is soft and almost free from odor, and in ideal situations should occur after each meal. The stool should be light colored and float on water and can be expelled from the body under minimal pressure. In an ideal healthy colon, the body wastes are promptly discharged and the colon should never contain the residues of more than two meals. The morning pre- or after-breakfast bowel movement should result in a near-complete emptying of the bowel.

To have a healthy colon, it is essential to include spices, vegetables, fruits, nuts, and whole grain cereals as part of our diet. Special diets are also prescribed to restore normalcy to the gut during pregnancy, childbirth, and lactation. It is believed that there is no part of the

body that cannot be healed by optimum gut health and the use of appropriate herbs and prescribed foods. During pregnancy, for example, yellow yams, fruits of *Chrysophyllum albidum*, *Gnetum* leaves, mangoes, various green vegetables, and plantains (*Musa*) are recommended. Spicy fish soups prepared with *Xylopia aetiopica*, lemongrass, *Tetraptera tetrapleura*, *Piper guinense*, etc. have been used by many African cultures as postpartum food. Palm wine made from raffia or palm tree is consumed after childbirth to improve lactation.

African children are more vulnerable to the many effects of an unhealthy gut. The continent has a high incidence of diarrheal diseases, especially among infants and toddlers, and the mortality rate of children less than 5 years of age is extremely high. The disease accounts for 37% of childhood deaths in sub-Saharan Africa. It has been noted by Feachem and Jamison[2] that an African child has a 10% chance of suffering from diarrhea on any given day and a 14% chance of dying from a severe episode of diarrhea.

7.2 Gut Microbiota

Humans have coevolved with their microbes over thousands of years and the resultant symbiont is a product of the interaction among the host (human), the environment, and cultural norms, including diet. But this relationship is now being dramatically affected by shifts in the human microbiome resulting from drastic and sustained changes in the environment and societal norms. Resulting perturbations of intestinal host–microbe interactions can lead to miscues and altered host responses that increase the risk of pathogenic processes and promote "Western" disorders such as inflammatory bowel diseases, cancers, obesity, diabetes, autism, and asthma. A major functionality of the African diet is in the cultivation and maintenance of a healthy gastrointestinal microbiota. This is achieved by the deliberate consumption of certain spices, bitters, and fermented and fermenting foods through which live bacteria are introduced to the gut system. The GIT harbors trillions of microorganisms that are indispensable for health. The literature indicates that shortly after birth, the GIT is colonized by a wide variety of different bacterial species. It is estimated that about 100 such microbial species populate the colon at birth. Perinatal exposure is a function of highly variable birth experiences within and across cultures, from the almost sterile cesarean delivery in a hospital surgical suite to a vaginal birth in a traditional village home with its hygiene challenges. It has been shown that the influence of the gut microbiota on human health is continuous from birth to old age. Early environmental factors, nutrition, and epigenetic considerations have been implicated in the composition of the gut microbial symbiotic community. The microbial community within the human infant gut varies as a function of bacterial exposure, successful colonization, and sustained nutrition.[3] The infant gut biome includes microbes that are present in human milk and on the skin of mother's breast.[4] Bacteria living in the human body make up more than 90% of the cell types in the body. They outnumber human cells 10 to 1 and account for 99.9% of the unique genes in the body. Most live in the colon, which contains over 500 different bacterial species.

Microbiologists have long established that the microflora of the gut of healthy individuals differ remarkably from those found in diseased persons. As was indicated earlier, disruption of the integrity of the gut microbiota can lead to many diseases. They include gastrointestinal ailments such as Crohn's disease and nonalcoholic fatty liver disease, digestive disorders such as chronic reflux, ulcerative colitis, and celiac disease,

cardiovascular disease, asthma and allergies, and autoimmune diseases such as multiple sclerosis and rheumatoid arthritis.[5] It is therefore essential that a major component of the search for good health should include taking substances that promote good gut microbiota. The vast number of microbes in the gut constitute about 60% of the luminal content of lower GIT and these commensal bacteria, weighing up to 2 kg, have been described as "an organ within an organ" and also as "a virtual superorgan" because of their functional role in human health.

The microbiota controls intestinal homeostasis through numerous mechanisms in which substances such as lipopolysaccharides (LPS), flagellins, peptidoglycans, and formylated peptides are involved. It interacts with intestinal cell receptors such as Toll-like receptors and activates important intracellular signaling pathways with the ability to modulate processes such as cell survival, replication, and apoptosis as well as inflammatory response. Among the challenging molecules are NF-κB, caspases, and mitogen-activated protein kinases. The host immune system controls the microbial composition through the release of molecules such as defensins, cryptidins, lectins, angiogenin, reactive oxygen species, IgA, and the so-called bacteriocins, which effectively limits the expansion of various pathogenic microorganisms.[6]

The gastrointestinal microbiota can be studied using culture and molecular methods. The introduction of massive sequencing due to the high yield of these organisms, increasingly accessible costs, and the availability of free software for data analysis have made it possible for detailed evaluation of a large number of studies on the gastrointestinal microbiota and its influence on human health; particular emphasis is placed on the evidence suggesting a relationship between the gastrointestinal microbial ecosystem and diverse physiological and immune/inflammatory processes. Studies have established conclusively that gastrointestinal microbiota play a critical role in human health and its possible alteration as a medical intervention to maintain, reestablish, and enhance health in the human host.[7] Even in organs that used to be considered sterile, such as the esophagus and lungs, microbiota have been found that may contribute to the pathogenesis and progression of disease.[8]

Like all living organisms, the gut microbiota is sensitive to a variety of compounds, and toxins from food and/or chemicals generated from putrefied food remnants affect their functionality. During constipation, the biota is not only poisoned by the toxins released into the GIT but the physical stress of hard-encrusted fecal matter causes damage to the lining of the colon, which in turn leads to ulcers, etc. The largely unregulated use of antibiotics also wreaks havoc on the microbiota, killing some of the good bacteria and distorting the natural balance of the system, which could lead to many disorders. Almost all human microbiome studies of the GIT are based on the collection of stool samples, which can potentially be limiting and misleading. First, the gut microbiota are not uniformly distributed throughout the GIT, but exhibit regional heterogeneity.[9] Their assemblage in these areas is determined by ambient conditions and available nutrients that are provided by their host as well as partnering microbes. It is also known that the mucosa-associated microbiota are quite distinct from those that are found in the lumen, the former being more stable and particularly adept in living with the host.[9]

Metagenomic studies have revealed that a large variability exist in the microbiota composition of individuals[10] but three distinct groups or the so-called "enterotypes" have been recognized, based on the predominance of one genus among *Bacteroides*, *Prevotella*, or *Ruminococcus*.[11] It has also been suggested that a more convenient categorization is that based on the ratio of abundance of *Bacteroides* and *Prevotella*, with the *Ruminococcus* enterotype folded into the *Bacteroides* group. Although host genetics seem to play a role in the

establishment and shaping of the gut microbiota, diet seems to be the core determinant for the formation of the different enterotypes.[12] It follows therefore that food consumption should be tailored not only for satiation and health benefits derived from the constituent phytochemicals but also to adapt to the specific individual or group enterotypes. It is also a logical assumption that there would be differential bioavailability among individuals in a given population depending on their enterotypes. Furthermore, herbal medicinal products could act primarily on the gut microbiota to improve the bioavailability of nutrients or restore biota integrity as immunity against certain diseases.

A metagenomic approach has been used to compare the composition of the gut microbiota of children (1–6 year olds) from Italy, who consume a Western-style diet (high in starch, sugar, and animal protein, low in fiber), and those from rural Africa (Burkina Faso), whose diet consists mainly of cereals, legumes, and vegetables (high in fiber, carbohydrates, and low in animal protein). The gut microbiota of the African children showed a highly significant enrichment in Bacteroidetes and a depletion in Firmicutes, with a unique abundance of bacteria from the genera *Prevotella* and *Xylanibacter*, which contain genes for cellulose and xylan hydrolysis, that were completely lacking in the European children. Furthermore, the gut microbiota was far more complex than that of European children. It has been suggested that the gut microbial richness may have a health-promoting effect by offering better protection against pathogens and gastrointestinal disease. The authors hypothesized that the African diet correlated with a gut microbiota that allowed maximum energy intake from fibers while at the same time protecting against inflammation and noninfectious colonic disease.[13] It is therefore essential that the traditional African diet pattern should be adhered to as closely as possible in order to maintain the integrity of the gut microbiota, thereby reducing the vulnerability of African societies to diseases that are alien to the African environment and which their bodies cannot handle as well as their Western counterparts with longer exposure to such diseases.

Diet is the most powerful influence on gut microbial communities in healthy human subjects.[14] A study of human subjects and 59 other mammals revealed clusters in which the effects of diet (carnivorous, omnivorous, or herbivorous) almost always outweigh host phylogeny.[15] *Bacteroides* spp. are prevalent with long-term protein and animal fat diets, whereas *Prevotella* spp. are associated with long-term carbohydrate diets.[16] The microbiota of Westerners is significantly reduced in comparison to those of rural Africans or individuals living a similar lifestyle to our Paleolithic forefathers. The great majority of ingredients in the industrially produced foods consumed in the West are absorbed in the upper part of the small intestine and thus of limited benefit to the microbiota. Lack of proper nutrition for microbiota has been identified as a major factor underpinning dysfunctional microbiota, dysbiosis, chronically elevated inflammation, and the production and leakage of endotoxins through various tissue barriers.[16] Studies have shown that high fat content of food, rather than high carbohydrate content (which dominates in most African cuisine) correlates with high levels of endotoxemia. Fat in foods is likely to negatively influence microflora and its replication, but the most pronounced effects are expected from their translocation-facilitating ability that is, to serve as vehicle for translocation of endotoxin, embedded in fat, through the mucosa and into the circulation, a process referred to as transcellular transportation. Diseases that have been shown to be associated with increased endotoxin in plasma include AD and cognitive impairment, arterio-coronary disease and stroke, diabetes, and cancer, as well as allergy, ALS, autism, autoimmune diseases, bipolar disease, chronic fatigue syndrome, COPD, minimal encephalopathy, fibromyalgia, HIV, liver cirrhosis, macular degeneration, nephropathies, rheumatoid disease, schizophrenia, stress, uveitis, obesity, osteoarthritis, paradontosis, and PD.[16]

A study has been published in which volunteers living for 1 month on a Western-style diet demonstrated, in a crossover study, a 71% increase in plasma levels of endotoxin activity (endotoxemia) when compared to those consuming what the authors described as a prudent-style diet, who demonstrated a 31% reduced level of endotoxin(s).[17] A positive correlation has also been reported between sedentary lifestyle and higher levels of endotoxin levels and a negative correlation to the degree of physical exercise.[18]

7.3 Probiotics, Prebiotics, and Symbiotics

A characteristic feature of the gut microbiota is their affinity for probiotics; these are living nonpathogenic organisms that provide health benefits by improving the microbial balance. Additionally, they are described as containing health benefits beyond those of basic nutrition and are often referred to as "friendly" or "good" bacteria. Although the use of fermented foods that introduce friendly bacteria is well known in the traditional African diet, the first probiotic food product that was promoted in Europe and North America was only in the 1920s with the introduction of acidophilus milk, which was sold as a supplement for digestive problems. In controlled clinical trials, probiotic bacteria have demonstrated a benefit in treating gastrointestinal diseases, including pouchitis, traveler's diarrhea, hepatic encephalopathy, prevention of infection after pancreatitis, allergic disease, irritable bowel syndrome, infectious diarrhea in children, and recurrent *Clostridium* deficit-induced infection, among others. Unfortunately, African probiotics and prebiotics have neither received much attention nor been studied in at any serious level in order to identify which strains may be suitable for therapeutic purposes. According to the FAO/WHO characterization, such a strain must be of human origin; resist acid and bile; and adhere, colonize, and survive in the human intestine. They must be safe for human use, have clinically validated health effects, and be suitable for commercial production.[19] Many probiotics are available in the form of fermented milk products such as yogurts and similar dairy products in which beneficial microbes are cultivated in edible substrates and formulated as health foods. In many African cultures, such fermented milk products are further fortified with herbs, cereals, and spices.

One initiative to make probiotics available to the rural poor is the Yoba-for-Life (www.yoba4life.com). The project uses a generic *Lactobacillus rhamnosus* GG to produce healthy yogurt in community kitchens and private homes in Uganda, Zambia, and other East African countries.[20]

It is now fairly well established that probiotics have the potential to alter the intestinal flora in favor of beneficial bacteria, thus affecting the immune and inflammatory response.

The mechanisms may include enhancing epithelial barrier function, modulating epithelial cytokine secretion into an anti-inflammatory dominant profile, altering mucus production, changing bacterial luminal flora, modifying the innate and systemic immune system, and inducing regulatory T-cell effects. Although the exact mechanisms of the health-improving properties of probiotics are still not completely understood, but are commonly suggested to relate to pathogen interference, exclusion or antagonism, immunemodulation, anticarcinogenic and antimutagenic activities, alleviation of lactose intolerance symptoms, reduction in serum cholesterol levels, reduction in blood pressure, prevention and decreasing incidence and duration of diarrhea, prevention of bacterial vaginosis and urinary tract infection, maintenance of mucosal integrity, and improved periodontal health.

Chapter 5 of this book includes a discussion on fermented African foods, which describes the various microorganisms involved in the transformation of certain foods to more edible forms. The residual microorganisms from the fermented products are of immense benefit to the GIT.

The relationship between gut microbiota and life-threatening extreme systemic inflammation response syndrome (SIRS) has been studied. It was reported that the study involved a total of 25 patients with severe SIRS and a serum C-reactive protein level >10 mg/dL.[21] Analysis of gut microbiota revealed markedly lower total anaerobic bacterial counts, particularly of the beneficial *Bifidobacterium* and *Lactobacillus* and higher counts of total facultative anaerobes such as *Staphylococcus* and *Pseudomonas* compared to healthy volunteers. In patients with bacterial translocation, Gram-negative facultative anaerobes were the most commonly identified microbial organisms in mesenteric lymph nodes and serosal scrapings at laparotomy. It was clearly demonstrated that gastrointestinal complications were strongly associated with a significantly reduced number of total obligate anaerobes and highly increased numbers of *Staphylococcus* and *Enterococcus* and significantly decreased numbers of total obligate anaerobes and total facultative anaerobes. Another related study in 63 similar patients suggests impaired gastrointestinal motility as a significant marker of poor outcome.[22] Patients with ≥300 mL per day reflux from a nasal gastric feeding tube demonstrated significantly lower numbers of total obligate anaerobes including Bacteroidaceae and *Bifidobacterium*, higher numbers of *Staphylococcus*, lower concentrations of acetic acid and propionic acid, and higher concentrations of succinic acid and lactic acid ($P \leq 0.05$), accompanied by dramatically higher incidences of bacteremia (86% vs. 18%) and mortality (64% vs. 20%) than patients without gastric distension ($P \leq 0.05$).[22]

Another class of substances that are important for the promotion and maintenance of good gut microbiota are prebiotics. These are substances that encourage the endogenous production of healthy gut bacteria. They consist mainly of nondigestible food ingredients, especially oligosaccharides that stimulate the activity of specific intestinal bacteria. Many natural bitters provide beneficial effects not necessarily through direct physiological activity but by promoting the production of beneficial microorganisms in the gastrointestinal system. Some herbs contain substances and indigestible components that provide prebiotic function to the gut. These include leaves of *Vernonia amygdalina*, *Gongoronema latifolia*, *Telfairia occidentalis*, and *Gnetum africanum*, rind of citrus fruits, avocado pear, mango peel, virgin coconut oil, Bambara nuts, tiger nuts, and *Ocimum* spp. A recommended method for good gut microbiota health is to adopt a synergistic approach that involves both the deliberate use of probiotics and prebiotic functional foods.

7.4 Gut and Immune System

Dysbiosis and impaired barrier functions are associated with several negative consequences: translocation of LPS and whole microbial cells, accumulation of endotoxin in the body (endotoxemia), and hyperactivation of the immune system. All living organisms are composed of cells as the fundamental unit of structure, function, and organization. It is the maintenance of the integrity of these cells that aggregate to good health. Owing to the developments in biochemistry, molecular biology, and pharmacology, many scientists have come to consider the effects of molecules as the sole cause of observed physiological function and not much contribution to the effects of cells on themselves. But it is

increasingly certain that the study of isolated parts cannot fully explain the pharmacodynamics of complex systems like the human body that is made up of many wholes. In the human body, which consists of many integrated systems that are joined together and with nonlinear interactions between them, the emergent properties can only be comprehended in the context of the whole system. Even for microbes, the cells also constitute a complex cell communication network through their interactions, and their cross-talk in signaling pathways and metabolic networks. When choosing the level of the cell, we can adopt a uniform conceptual architecture for all levels, viewing the organism as a network of interacting cells in the same way as we view the cell as a network of interacting molecules. Transcription factors and, in particular, assemblages of these, are special devices that not only interact with each other but also with special DNA sequences in gene promoters.

It follows from the above that almost all foods include macronutrients, vitamins, and phytochemicals, and even toxins can affect immunomodulation, activation or suppression of signal transduction, and metabolic regulation. Moreover, different experiments performed with the same samples result in remarkably different and even contradictory findings. So what can these data tell us? Which agents are beneficial for our health? In order to resolve these problems, we have to be clear as to which component is the agent of the biological function and how it exerts its activity *in vivo*. It has been suggested that the cell alone exerts most observed biological activities, that only the cell is the executor of biological functions, and the cell exerts its functions through interactions with each other, and that these interactions constitute a cellular communication network that occurs through signaling molecules in circulations. The cells in the gut accordingly serve as an early warning system for system defense against invading microorganisms and xenobiotics. It has been found that gut immunity is crucial for the balance between inflammatory and anti-inflammatory conditions at local and systemic sites. Experimental data and epidemiological indications have shown that alterations in the gut microbiota (i.e., dysbiosis) can be relevant in intestinal disorders such as chronic inflammatory bowel disease (IBD) and sepsis.[23]

7.5 Gastrointestinal Information Exchange System

The GIT is considered the most highly innervated organ in the body, and has the largest concentration of neurotransmitters outside the brain, including approximately 90% of the body's serotonin, supporting the view of a highly developed brain–gut communication pathway. The GIT maintains its function through its own internal nervous system, the enteric nervous system, and it is closely linked to the central nervous system through a complex interaction of the neuro–endocrine–immune systems, with the autonomic nervous system playing a central role in brain–gut communication. Available evidence suggests that the gut could be the switch that controls a mobile cell communication network in the human body. The host–microbiota interaction is not confined to the gut but includes a series of metabolic axes connecting the microbiota with the gut, brain, liver, and muscle.[24] Studies have shown that not only are allergy and autoimmune diseases linked to immune dysfunction derived from failure in gut–host communication, but so are other disorders, including obesity and its associated metabolic disorders such as type 2 diabetes.

The immune system, for example, is composed of a complex network of different cell types, including lymphocytes, DCs, macrophages, and neutrophils. Each has a specific

function, but all share the ability to move continuously throughout the body, constantly surveying peripheral tissues and lymphoid organs for the presence of potential pathogens. These cells are able to change their homeostatic recirculation program when they are informed of an infected site. Recruitment of immune cells to the site of infection is critical for mounting an immune response to fight off and clear away the invaders. Obviously, this is an information communication process, especially for mobile cells, such as leukocytes, and certainly confirms mobile cell communications networks.

The communication itself is mediated through a diverse group of soluble proteins, peptides, or glycoproteins called cytokines, which act as hormonal regulators or signaling molecules at nano-to-picomolar concentrations and help in cell signaling. They are produced throughout the body by cells of diverse embryological origin. The smaller cytokines, known as chemokines, are characterized by their ability to induce directional migration of cells by binding to chemokine receptors. Currently, more than 50 chemokines and 20 chemokine receptors have been described. The gut microbiota may constitute a complex metabolic network for communication relating to dietary nutrition and the host. The challenge may be to determine the temporal dynamics of metabolic communication between the host, diet, and gut microbiota, and to evaluate their real effects *in vivo*. Some functional foods, such as fibers and macromolecular substances in food, cannot be absorbed, yet they do impact cytokines and chemokines.

This means that almost everything can affect our health via the gut information exchange system, including nutrients, microbes, functional foods, medicines, pathogens, vaccines, and even toxins. Even the absorption, metabolism, and excretion of drugs are largely dependent on the status of the gut microbiota. Many food plants are useful for their role in maintaining optimum gut microbiota health and thereby impact the immunity of the body. The implication of this observation is that food substances do not necessarily have to be absorbed in the system to influence the function of the GIT and the whole body. It also raises the possibility that unknown substances consumed as food can create immense confusion in the gastrointestinal communication system, leading to aberrant immune responses.

7.6 Functional Foods, Gut Health, and Diseases

As indicated above, functional foods that contain edible dietary fibers (EDF), prebiotics, probiotics, and symbiotics have immense health benefits. Cereal grain bran fractions, seed coat and cotyledons of legumes, and endosperm cell walls are rich sources of EDFs. Such food substances are described elsewhere in this book (see Section I, Chapter 5), and individual monographs on the plants are also provided (Section III). Those EDFs that selectively promote probiotics (live microorganisms that confer health benefits on the host) and benefit host health are prebiotics. Studies have shown that dysregulation of normal gut flora might give rise to many inflammatory diseases such as obesity, IBD, type 2 diabetes mellitus (T2DM), arthritis, and cancer.[25] The restoration of gut equilibrium should be considered as a feasible part of the treatment options for metabolic disorders and chronic diseases. Ellagitannin-rich plant materials, for example, are widely used in traditional medicine as effective anti-inflammatory agents. In the case of external use, the results of *in vitro* experiments using extracts or isolated ellagitannins are easily applied to the observed *in vivo* effects. Yet, ambiguities arise when internal use is considered. Ellagitannin-rich

plant materials are often used in traditional medicine in internal treatment of different inflammation-associated diseases.[16] It has been established by laboratory studies that urolithin A, B, and C were formed by human gut microbiota following the oral ingestion of aqueous ellagitannin-rich extracts.[26] It was also reported that significant inhibition of TNF-α production was observed for all urolithins, while for the most potent urolithin A, inhibition was observed at nanomolar concentrations (at 0.625 μM, 29.276.4% of inhibition), with urolithin C as the only compound inhibiting IL-6 production (at 0.625 μM, 13.972.2% of inhibition). The gut microbiota is also believed to play a role in the control of body fat. The possible role of gut microbiota and obesity has been addressed by several researchers in recent years, indicating a possible therapeutic approach toward the management of obesity by the introduction of an external living system such as a probiotic.[27] The mechanism underlying this activity is attributed to metabolites produced by gut microbial organisms; this will include physiological factors such as gut hormone and lipid sensing involved in various tissues and organs, and most importantly by the role of gut microbiota in weight management.[28] A recent study reveals that gut microbiota hamper the emergence of thermogenic brown fat cells named beige cells within white fat depots via a mechanism that involves the control of macrophages and eosinophil infiltration.[29]

7.6.1 Carminatives, Flatulence, and Colic

Aromatic plants and spices such as *Ocimum* spp., *Tetrapleura*, *Xylopia*, lemon grass, peppermint, and alligator pepper are used in various proprietary formulations as carminatives to restore balance to upset stomachs. In Nigeria, "Dr. Sapara baby mixture," "ogbomoro," and "ogwu-umuaka" are infusions of essential oil-bearing plants used for the treatment of infantile flatulence and "stomach gripes." The Mano people of Liberia employ leaves of *Ipomoea digitata* and young figs (*Ficus* spp.) boiled with washed pebbles for the same purpose. Common colic medicines include *Afromomum* spp., exudates from various species *of Canarium*, volatile oil-containing plants, leaves of *Macaranga* spp., *Piper guineense*, and *Piper umbellatum.*

7.6.2 Laxatives and Purgatives

It was earlier stated that traditional African medicine considers constipation a serious problem; hence there are many herbs that are used to promote bowel movement. Laxation is easily accomplished by the ingestion of vegetables with high fiber content, with or without palm oil. For purgatives, the common cathartics include Aloes, the roots of *Euphorbia hirta*, leaves and seeds of the *Cassia* spp., bark of the *Harungana* spp., and *Alchornea cordifolia* leaves. The seeds of *Moringa oleifera* can be used to regulate bowel movement and the effect is determined by the number of seeds consumed.

7.6.3 Diarrhea and Dysentery

Diarrhea and dysentery are usually treated effectively by the administration of certain herbs. Bloody diarrhea is treated with a mixture of herbs and antimicrobial spices. The simple dietary diarrheas are said to be easily arrested by roasted fruits of *Musa sapientum.* Species of *Ficus*, *Entada*, *Gossipium*, *Maesoftrya*, and *Dichrostachys* are sometimes used for the treatment of systemic diarrheas. It is noteworthy that it has been claimed that acute intestinal obstructions and serious appendicitis are managed successfully by native healers without recourse to surgery.[30]

7.6.4 Gut and Psychotic Diseases

Although the gut is regulated through its own internal nervous system, there is a complex communication network that exists between the enteric nervous system and the central nervous system, via a complex interaction of the neuroendocrine–immune systems, with the autonomic nervous system playing a central role in brain–gut communication.[31] The communication is bidirectional, with brain status affecting GIT and gut health affecting normal brain function. For example, normal GIT functions, such as gastric emptying, transit time, and small and large intestine contractions can be altered by psychological processes such as emotion and stress.[32] Conversely, gut upset (e.g., loose stool, nausea) often makes people irritable, moody, and depressed. People living with GI disorders, particularly disorders that affect bowel habits, frequently report perceptions of being "unclean" and concerns about managing bodily odors. Foods such as aromatic teas, high-fiber cereals, and certain vegetables may contribute in the maintenance of nervous health by acting only in the gut without any direct CNS effect. It has been observed that patients with a critical illness, as well as patients with chronic disorders such as liver cirrhosis and diabetes, frequently suffer a mild but sometimes severe confusion, which often has its origin in the gut.[33] The available evidence suggest that ingestion of probiotics, alone but also in combination with plant antioxidants and fibers, possess strong neuro–endocrine modulatory effects and can alleviate the effects of physical and mental stressors.[34]

7.7 Maintenance of Optimum Gut Health

The main focus of this chapter is to underline the contribution of healthy gut to the functional attributes of African cuisine and to stress the difference between the African biome and those of other societies. Like other organs of the body, it is important to develop a sustainable methodology for the maintenance of gut health. The recommendations by Stig Bengmark[13] below is adopted (with modifications) as a reasonable framework for a healthy gastrointestinal system:

1. Minimizing intake of insulinogenic foods such as refined carbohydrates; cereals, bread, sweets, cookies, rice, pasta, cooked tubers, including potatoes, foods that are absorbed high up in the small intestine and are of minimal benefit to microbiota.
2. Keeping the daily intake of fructose below 25 g.
3. Minimizing the intake of dairy products, especially butter, cheese, and milk powder, rich in saturated fats, hormones, and growth factors such as IGF1, and reducing meat intake, especially inflammation-inducing processed and cured meat such as bacon and sausages, though so far only fat has been demonstrated to being detrimental to microbiota.
4. Dramatically increasing the intake of fresh and raw greens, fresh spices and vegetables, rich in antioxidants, fibers, minerals, and nutrients, but also inflammation-controlling factors such as curcumin and resveratrol—some of which are most likely of great importance for diversity, replication, growth, and functions of the microbiota and for immune development and immune functions of the body.

5. Minimizing intake of foods that are heated above 100°C, known to be rich in the inflammation-inducing molecules AGEs and ALEs, and foods heated above 130°C, which with the increase in temperature become increasingly rich in proinflammatory and carcinogenic substances such as acrylamide and heterocyclic amines. This means avoiding fried and grilled foods and also toasted and high-temperature baked breads.
6. Minimizing exposure to microbe-derived highly inflammation inducing endotoxin, especially rich in meat hung for several days, hard cheeses, pork, and ice creams.
7. Eliminating/minimizing intake of foods rich in proteo-toxins such as casein, gluten, and zein.
8. Seeking out and consuming ancient antioxidant-rich, high-fiber, low-calorie grains such as buckwheat, cowpea, amaranth, acha, chia, lupin, millet, quinoa, sorghum, taro, teff, etc., and also increasing the intake of beans, peas, chickpeas, lentils, nuts, and almonds, all extraordinarily rich in nutrients and minerals, all prepared for eating by low-temperature cooking, and all most likely of importance for the maintenance of a rich microbiota.
9. Restricting the intake of chemicals, including pharmaceutical drugs, to only what is absolutely necessary as it is most likely that most chemicals are detrimental to microbiota.
10. Supplementing with large doses of vitamins, especially vitamin D and omega fatty acids; both are important in controlling inflammation and for the function of microbiota.
11. Avoid eating much "bush meat" or game meat. Very little data exist about the health hazards of game meat, which despite its favorable nutritional profile when compared to farmed meat is often kept hanging for weeks and, as a consequence, is especially rich in endotoxins.
12. Consume as much of locally produced food as possible. The further the site of food production, the more likely it will be contaminated with preservatives and storage chemicals.

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8

Functional Foods and Phytonutrients in Diabetes Management

8.1 Introduction

The maintenance of normal blood glucose levels is important for the prevention of chronic diseases such as diabetes, cardiovascular diseases, and obesity. *Diabetes mellitus* (DM) is actually not a single disorder, but a collection of conditions with a common end result of raised blood glucose.[1] Diabetes as discussed in this section refers only to the so-called T2DM, which is a chronic metabolic disorder characterized by a high blood glucose concentration (hyperglycemia) due to insulin deficiency and/or insulin resistance. Hyperglycemia occurs because the liver and skeletal muscle cannot store glycogen and the tissues are unable to take up and utilize glucose. It is a serious, life-long disorder that is, as yet, incurable. Although diabetes can only be determined by the laboratory measurement of fasting blood sugar levels, the disease sometimes presents diagnostic symptoms that include increased thirst as well as increased frequency and volume of urine production. Diabetes in most cases is symptomless and is often not detected until it has caused some systemic damage. If left untreated, diabetes mellitus may lead to death due to acute metabolic decompensation producing dehydration and acidosis. Chronic diabetes often results in damage to a number of organs, including the kidneys, blood vessels, nervous system, and eyes.

According to the International Diabetes Federation,[2] as of 2015, there were about 415 million adults worldwide living with diabetes and this figure is estimated to rise to 642 million by 2040, with 109.6 million affected in China and 69.3 million in India. Type 2 diabetes constitutes about 90% of the cases, which is equal to 1 in 11 of the adult population and with almost equal rates in both women and men. In 2015, it was reported that diabetes resulted in 5 million deaths per year worldwide, making it one of the leading causes of human mortality, above the deaths recorded for HIV-AIDS, tuberculosis, and malaria. Diabetes overall at least doubles the risk of death from other comorbidities.

Diabetes exerts immense economic burden, including the provision of blood sugar testing and monitoring kits, high costs of antidiabetic drugs, the expenses incurred to purchase special diets and preventive medicines, and the treatment of complications arising from diabetes. Some of those affected may be unable to work and support their families. The economic cost of diabetes globally was estimated at $755 billion in 2015, with countries spending up to 20% of their total health expenditure on diabetes.

Abnormally high blood sugar and obesity have become indicative of a disease complex known as metabolic syndrome (MetS), or syndrome X, which is a group of risk factors that commonly occur together and include hypertension, abdominal obesity, dyslipidemia, and dysglycemia. These risk factors increase the risk for chronic comorbidities, particularly

cardiovascular disease, diabetes, and nonalcoholic fatty liver disease. In fact, individuals with MetS are twice as likely to develop cardiovascular disease and have a fivefold increase in the risk of T2DM. The incidence of MetS, along with obesity rates, is rising at staggering rates in Westernized countries (which coincides with the rising rates of chronic disease). In the United States, it is estimated that 69 million people (34.5%) have MetS. The incidence in the United Kingdom, Germany, Italy, and some European countries parallel that of the United States.

Prevention of type 2 diabetes involves a healthy diet, physical exercise, no tobacco usage, and maintaining a normal body weight. The first line of intervention in the management of diabetes (and by inference, MetS) is a diet and exercise regime, which may be followed by the use of oral hypoglycemic agents, and/or insulin replacement therapy. Blood pressure control and proper food care are also important for people with the disease. Many herbal medicinal agents and phytochemicals have been reported in the literature as beneficial in the management of diabetes. Some of these are phytonutrients found in edible food substances. Therefore, careful selection of functional food alone may be sufficient in the management of diabetes and its complications.

Current treatments for diabetes are not fully effective when administered as monotherapies due to the complex regulatory networks involved in T2DM.[3] Therefore, multicomponent natural extracts and plant products offer the advantage of possessing diverse chemical structures with different targets[4] and may be more effective than single-target-based pharmaceuticals.[5] Many herbal preparations are available for the management of diabetes in traditional medicine but only a few have been evaluated. Some of the medicinal plants used in the preparation of such remedies have been shown to contain many physiologically active phytochemicals that improve glucose metabolism and lipid levels and provide beneficial antiatherogenic and hormonal effects. Some of them are in various stages of development as phytomedicines and/or phytopharmaceutical agents. A subset of the botanical antidiabetic agents is the nutraceuticals or phytonutrients group that are derived entirely from food plants or common herbs. Since a major aspect of the management of diabetes is the control of food intake to minimize the consumption of food with high glycemic index in preference to those with lower glycemic index, these edible herbal dietary supplements provide feasible ingredients for the preparation of antidiabetic soups and meals.

Naturally occurring phenolic compounds that are distributed widely in plants such as flavonoids, procyanidins, and catechins have been shown to be responsible for the antidiabetic activities of many edible vegetables and fruits. They constitute an important component of human diet. Consumption of red wine (rich in flavonoids) is associated with low cardiovascular mortality rate in the Mediterranean population and has been popularly quoted in the literature as the "French paradox." Flavonoids and procyanidins are capable of improving, stabilizing, and sustaining insulin secretion, pancreatic islets, and pancreatic cell activities. Although the antidiabetic properties of these plant phenolics have been demonstrated in many laboratory studies and clinical trials, their pharmacodynamics is problematic on account of their deprived solubility, decreased bioavailability, first-pass metabolism, and intestinal degradation.

8.2 Functional Foods

Outlined below is a select list of major herbs or food plants that are used as nutritional supplements in the management of diabetes and/or its complications. This list excluded

those plant products or structurally characterized and chemically defined single isolates that are considered as potential phytopharmaceutical agents.

8.2.1 Aduwa (*Balanites aegyptiaca*)

The African "desert date" is used in traditional medicine for the treatment of diabetes. The aqueous extract of the mesocarp of *Balanites* has been found to show significant antidiabetic activity in drug-induced diabetic rats and mice. The observed activity was believed to be due to the presence of several saponins in the fruit. Further studies are ongoing aimed at the identification of the target tissues and mechanisms of action of this herb. *Balanites* is used throughout the African Sahel region as an antidiabetic drink.

8.2.2 Aloes

Aloe vera (*Aloe barbadensis*) and cape aloe (*Aloe ferox*) have been used in the management of diabetes mainly as the major ingredient in polyherbal formulations. In an experimentally induced diabetes study, adult male albino rats were made diabetic by single-dose intraperitoneal injection of streptozotocin (50 mg/kg body weight). The extracts of *Aloe vera* showed significant antidiabetic activity when compared to the antidiabetic drug glimiperide.

Both aloe extract (10 mL/kg, p.o.) and glimiperide (10 mg/kg, p.o.) significantly decreased serum glucose and significantly increased serum insulin levels as compared to control diabetic rats. Serum levels of malondialdehyde (MDA) and superoxide dismutase (SOD) were significantly decreased while blood glutathione (GSH) was significantly increased by aloe treatment as compared to diabetic rats. In an *in vitro* assay, the effect of aloe was better than the effect of glimiperide. Both aloe and glimiperide significantly increased both basal and stimulated insulin secretion from the isolated pancreatic islets of Langerhans as compared to control. The glucose-lowering activity of *Aloe vera* is believed to be mediated, at least partially, through its potent antioxidant effect. This has tremendous clinical benefit as a supplement as recent approaches suggest that treatment of diabetes should not only focus on insulin secretion but also on antioxidant protection of the β-cell. This property may facilitate the repair of β-cells undergoing damage by oxidative stress secondary to hyperglycemia. A clinical study has shown that in obese individuals with prediabetes or early untreated DM, aloe–gel complex reduced body weight, BFM, and insulin resistance.

8.2.3 Banaba (*Lagerstroemia speciosa* L.)

Lagerstroemia speciosa has been used as a folk medicine among people with diabetes, especially in the Philippines. It is known to exhibit antidiabetic, antiobesity, and glucose transport activities through mechanisms not well defined. Diabetes leads to cardiomyocyte hypertrophy in association with an upregulation of vasoactive factors and activation of NF-κB and activator protein-1. *Lagerstroemia speciosa* has been shown to be effective against the activation of NF-κB, a key mediator of cardiomyocyte hypertrophy, in rat cardiomyocyte H9c2 cells. Banaba leaves contain corosolic acid as the active component with proven hypoglycemic and hypocholesterolemic effects. Corosolic acid inhibits gluconeogenesis and stimulates glucose uptake. An oral dose of 1% corosolic acid at 48 mg/day in a soft gel format has been found to support 30% improvement in glucose levels.

8.2.4 Bitter Melon (*Momordica elegans*)

This is a well-established Asian antidiabetic plant that is grown throughout the tropics. Dietary use of bitter melon or its juice decreases blood glucose levels, increases HDL cholesterol, and decreases triglyceride levels, thus exhibiting antiatherogenic qualities. Extract of bitter melon in supplement form has been widely used as a traditional medicine for diabetic patients. When administered alone, it has a modest hypoglycemic effect at doses of at least 2000 mg/day. This botanical supplement enhances the cellular uptake of glucose and promotes insulin release, potentiating its effect, and in animal studies has been shown to increase the number of insulin-producing beta cells in diabetic animals. Bitter melon has also been found to reduce adiposity and oxidative stress in addition to reducing blood triglycerides and low-density lipoproteins.

8.2.5 Bitter Kola (*Garcinia kola*)

Garcinia kola is used extensively in West African traditional medicine for the treatment of laryngitis, general inflammation, bronchitis, viral infections, and diabetes, as well as a rejuvenating agent, adaptogen, and general antidote. Kolaviron, the mixture of biflavonoids, benzophenones, and chromanols, and related phenolic compounds in *G. kola* possess strong antioxidant activities. Several reports on the experimental validation of the antioxidant properties of *Garcinia* are essentially due to kolaviron. An evaluation of the antioxidant properties of garcinoic acid (structurally similar to vitamin E) and its congeners, including investigation of the structure–antioxidative activity relationships, identified a semisynthetic derivative with antioxidant activity that was 18 times stronger than DL-α-tocopherol. The aqueous extract showed antidiabetic activity in hyperglycemic rats. At a concentration of 200 mg/kg body weight, over a period of 21 days, the extract significantly ($P < 0.05$) decreased the blood glucose level, increased the activity of SOD ($P < 0.05$), and that of MDA ($P < 0.05$). The extract however had no significant effect ($P > 0.05$) on the activity of catalase. Perhaps the greatest value of bitter kola extract is prevention and management of diabetic complications of the eye because of its activity on aldose reductase.

It is intriguing that bioflavonoids of *Garcinia kola* are capable of modulating almost any physiological anomaly. The answer perhaps lies in the role of flavonoids in the evolutionary course of human beings. Humans, over many millennia, have adapted to a diet that is favorable for their survival and the flavonoid-like structures were part of the physiological scheme.

8.2.6 Bitter Leaf (*Vernonia amygdalina*)

Vernonia leaves are used in West Africa as a highly valued vegetable in soups. The major activities found in many laboratory and clinical studies on *Vernonia amygdalina* include antimalarial, antidiabetic, antioxidant, antihypercholesterolemic, anthelmintic, uterine contractility, immune boosting in HIV infections, and anti-inflammatory properties. *Vernonia amygdalina* holds tremendous promise for development into a nutraceutical against diabetes and malaria. It has been found that a decoction containing a mixture of *Vernonia*, *Gongronema*, and *Ocimum* was found to be superior in antidiabetic activity to any one, or blends of only two, of the three plants. A proprietary product by Intercedd Health Products and Neimeth Pharmaceuticals called Physogen Plus™ contains the three vegetables and *Garcinia kola*.

8.2.7 Chaste Tree Berry (*Vitex agnus-castus*)

Vitex agnus-castus is better known for its use in the treatment of premenstrual syndrome but has been found increasingly valuable in polyherbal antidiabetic teas because of its ability to improve function of the hypothalamic–pituitary–adrenal axis, enhancing the often-overlooked but important hormonal influence of this system on blood glucose regulation. Hormonal dysregulation and distress increase risk from syndrome X and insulin resistance, as well as associated complications.

8.2.8 Cinnamon (*Cinnamomum zeylanicum*)

Cinnamon is recognized as a highly valuable functional food in the management of type 2 diabetes. The bioactive compounds and the polyphenols in cinnamon appear to mimic the effect of insulin through increased glucose uptake in adipocytes and skeletal muscles. The blood glucose lowering potential and pharmacological properties of cinnamon has been demonstrated previously in *in vitro* and *in vivo* animal studies. A systematic review and meta-analysis that examined the effect of cinnamon on glycemic control in patients with T2DM indicates that the use of cinnamon showed a beneficial effect on glycemic control (both HbA1c and FPG) and the short-term (<4 months) effects of the use of cinnamon on glycemic control suggest a positive role as a dietary supplement in diabetes management.

8.2.9 Clove Oil (*Eugenia aromaticum*)

Cloves have been found useful in the treatment of chronic diabetes. It has been shown that dietary supplementation with cloves reduced tissue injuries, especially in the lens and cardiac muscles, and to a lesser extent in the liver but not the kidneys. Additionally, treatment with cloves significantly reduced blood sugar increases and lipid peroxidation in streptozotocin-induced diabetic rats by restoring the antioxidant enzyme levels. Cloves inhibited hyperglycemia-induced oxidative tissue damage and cataract formation in the eye lens. This study demonstrates the *in vivo* antioxidative organ-protective effects of clove in diabetics.

8.2.10 Cocoa Polyphenols (*Theobroma cacao*)

Cocoa extracts rich in polyphenols have been shown to be beneficial in the management of diabetes but the mechanisms for their preventive activities as they relate to glucose metabolism and insulin signaling in the liver remain largely unknown. Insulin resistance, which is the primary characteristic of type 2 diabetes, has been shown by several studies to be ameliorated by cocoa and its main flavanol, (–)-epicatechin (EC). In laboratory studies, dietary supplementation with cocoa liquor procyanidins has been observed to prevent dose-dependently the development of hyperglycemia in diabetic obese laboratory animals. The preventive effect of EC and cocoa polyphenolic extract (CPE) on insulin signaling and on both glucose production and uptake has also been studied in insulin-responsive human HepG2 cells treated with high glucose.

It has been shown that pretreatment of cells with EC or CPE reverted decreased tyrosine-phosphorylated and total levels of IR, IRS-1, and IRS-2 triggered by high glucose. EC and CPE pretreatment also prevented the inactivation of the serine/threonine kinase (Akt), phosphoinositide 3-kinase (PI3K), protein kinase B (AKT/PKB) pathway and AMPK (5′-AMP-activated protein kinase), as well as the diminution of GLUT-2 levels induced by

high glucose. Furthermore, pretreatment of cells with EC and CPE avoided the increase in PEPCK (phosphoenolpyruvate carboxykinase) levels and the diminished glucose uptake provoked by high glucose, returning enhanced levels of glucose production and decreased glycogen content to control values. These findings suggest that EC and CPE improved insulin sensitivity of HepG2 treated with high glucose, preventing or delaying a potential hepatic dysfunction through the attenuation of the insulin signaling blockade and the modulation of glucose uptake. A significant improvement in glucose and insulin responses during oral glucose tolerance tests was observed after flavonoid-rich but not after flavonoid-free chocolate ingestion in healthy volunteers and hypertensive patients, with and without impaired glucose tolerance.

Major perturbations in skeletal muscle oxidative stress associated with type 2 diabetes and heart failure patients can be reversed with cocoa epicatechin. Decreases in oxidative stress may be due to the modulation of key regulatory pathways, including antioxidant levels (e.g., glutathione) and enzymes such as mitochondrial superoxide dismutase (SOD2) and catalase. The cocoa polyphenols may provide an effective means to treat conditions associated with tissue OS.

8.2.11 Coconut, Virgin Coconut Oil (*Cocos nucifera*)

The juice of the young spadix of coconut, *Cocos nucifera* Linn. (Arecaceae), is traditionally used for the treatment of diarrhea and diabetes. In laboratory studies, hydromethanol extract of coconut showed a significant reduction in the fasting blood sugar level in treated animals as compared with diabetic control groups. Serum enzyme level (SGOT, SGPT, SALP), lipid peroxidation, and antioxidant enzyme level such as CAT, GSH, SOD, and cholesterol and triglycerides in the coconut-extract-treated groups were restored toward normal level as compared to diabetic control groups and the values were comparable with the standard groups on the oral antidiabetic drug, glibenclamide.

Virgin coconut oil (VCO), which is prepared by cold press, helps control blood sugar, and improves the secretion of insulin. It also helps effective utilization of blood glucose, thereby preventing and treating diabetes. Although coconut oil is a saturated fat, several studies have found that eating VCO does not have adverse effects upon the heart. On the contrary, it appears to reduce the risk of high cholesterol and heart attack. VCO should not be confused with refined coconut oil produced from dried copra or so-called partially hydrogenated coconut oil. Unlike refined coconut oil, which is produced through the dry method from copra, VCO is produced through the wet method, via coconut milk. Many ways of producing coconut oil have been described in the literature, so the source of the VCO for optimum health benefits is very important. VCO contains some phenolic acids such as protocatechuic, vanillic, caffeic, syringic, ferulic, and *p*-coumaric acids. The studies suggest that the contribution of antioxidant activity in VCO could be due to these phenolic compounds.

8.2.12 Fenugreek (*Trigonella foenum-graecum*)

Perhaps the most studied herb in the management of diabetes, fenugreek has been found to lower both blood glucose and lipids. Fenugreek decreases insulin resistance and decreases triglyceride levels. Fenugreek can safely be used as an adjunct and in combination with sulfonylureas in the treatment of type 2 diabetes. Extracts from this herb have been shown to decrease lipid content of liver, inhibit gluconeogenesis, stimulate glycolysis, and overall to be more effective, with fewer side effects, than the commonly prescribed medication tolbutamide.

8.2.13 French Lilac (*Galega officinalis*)

Galega officinalis has been known since the Middle Ages as a folk remedy for relieving the symptoms of diabetes mellitus. The aerial parts of this plant are used traditionally for the treatment of diabetes in many countries. The active ingredient in this plant that decreases blood sugar by decreasing insulin resistance is galegine or isoamylene guanidine.

One of the most widely used oral hypoglycemic drugs in clinical medicine, metformin owes its origin to the traditional use of *Galega officinalis* for the management of diabetes. An extract of the plant produced the active constituent galegine. The analog, metformin, was then made by Jean Sterne and named "glucophage," which means "glucose eater," in reference to its hypoglycemic qualities. It was first introduced into clinical medicine in 1958 backed by many clinical reports of its effectiveness in diabetes.

8.2.14 Garlic (*Allium sativum*)

Garlic and its constituents have been shown to possess diverse biological activities, including antidiabetic, antitumorigenic, anticarcinogenic, antiatherosclerotic, antithrombotic, and various other biological actions. Garlic are of two basic types: hardneck and softneck. Hardneck garlics, which include *A. sativum* var. *ophioscorodon* and *A. sativum* var. *pekinense*, are characterized by hard, woody central stalks that extend down to the basal plate at the bottom of the bulb. Garlic is one of the most popular herbs used worldwide to reduce various risk factors associated with diabetes and cardiovascular diseases. Garlic, a member of the Liliaceae family, is a common food flavor and spice, and is one of the herbs most commonly used in modern folkloric medicine. It is available as raw unprocessed material and in various formulations.

The antidiabetic properties of garlic have been demonstrated in many laboratory and clinical studies. It has been shown that treatment with garlic bulbs can improve glycemic control via significantly improved insulin sensitivity, glucose tolerance, insulin secretion, and improved glucose utilization by skeletal muscle in the presence of insulin. Diallyl trisulfide and *S*-allylcysteine are important functional components of the hypoglycemic effect of garlic.

8.2.15 Ginger (*Zingiber officinalis*)

Preclinical and clinical randomized double-blind studies have demonstrated the beneficial effect of ginger in the management of type 2 diabetes. Ginger possesses hypoglycemic effects in both normal and diabetic animals. It reduces the diabetic complications such as cardiovascular diseases, cataract, nephropathy, neuropathy, and infertility. These actions of ginger are shown to be mediated through its antioxidant potential, correction of dyslipidemia, inhibition of polyol pathway of sorbitol formation, inhibition of formation of AGE, and inhibition of α-glucosidases. Ginger possesses an insulinotropic effect and enhances insulin sensitivity of peripheral tissues, and has an antagonizing effect on serotonin-mediated suppression of insulin release. In a controlled double-blind clinical trial with standardized extracts of ginger, it was shown that daily consumption of three 1-g capsules of ginger powder for 8 weeks is useful for patients with type 2 diabetes due to FBS and HbA1c reduction and improvement of insulin resistance indices such as the QUICKI index.

8.2.16 Golden Root (*Rhodiola rosea*)

Rhodiola rosea is used primarily for the treatment of fatigue and sometimes for cognition and mood enhancement. It has also been found useful as a possible adjunct in diabetic therapy because of the pharmacological evidence of use in fatigue and its effectiveness in supporting cognition and mood disorder. The plant is considered an adaptogen with cardioprotective effects, and improved levels of β-endorphin production.

8.2.17 Gongronema, Utazi (*Marsdenia latifolia*)

Utazi is valued as an ingredient for the preparation of bitters. It is a major constituent of the popular antidiabetic tea, Physogen™, produced by the International Centre for Ethnomedicine and Drug Development (InterCEDD), Nsukka, Nigeria and marketed by Neimeth Pharmaceuticals and Intercedd Health Products. Several laboratory studies have demonstrated the possible antidiabetic activity of *Gongronema*. Different alcoholic leaf extracts showed promising hypoglycemic and antihyperglycemic activities in a dose-dependent way on normal and alloxan-induced or streptozotocin-induced diabetic rabbits. An ethanolic leaf extract possessed significant antilipid peroxidative activities. In a small clinical trial, the blood glucose concentration of healthy humans was determined after consumption of the leaves and showed a significant reduction in blood glucose level. Leaf extracts also showed antioxidant, anti-inflammatory, hepatoprotective, antiplasmodial, antiasthmatic, antisickling, antiulcer, analgesic, antipyretic, gastrointestinal relaxing, laxative, and stomachic activities.

8.2.18 Guava Leaves (*Psidium guajava*)

Guava leaves are used extensively in teas as a hypoglycemic agent. Although the plant is better known in phytotherapy for its antispasmodic and antimicrobial properties in the treatment of diarrhea and dysentery and in cosmetic formulation for its skin-healing properties, many pharmacological studies have demonstrated the ability of guava to exhibit antioxidant, hepatoprotection, antiallergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, cardioactive, anticough, antidiabetic, anti-inflammatory, and antinociceptive activities, supporting its traditional uses. Available studies suggest a wide range of clinical applications for the treatment of infantile rotaviral enteritis, diarrhea, and diabetes. Its use in the management of type 2 diabetes is supported by many clinical and laboratory studies. Guava leaves contain tannins as well as β-sitosterol, flavonoids, triterpenoids, and volatile oil.

8.2.19 Gymnema or Melyna (*Gymnema sylvestre*)

The herb enjoys tremendous popularity in traditional medicine as an antidiabetic agent. The Sanskrit name for the plant is "gurmar" meaning "sugar destroyer," perhaps due to its unusual effect of temporarily suppressing the ability to taste sugar when applied to the tongue. Several studies have been conducted on both the crude extract and isolated compounds, and it is now firmly established that *Gymnema* possesses the following properties: (a) inhibition of intestinal glucose absorption as evidenced by human and animal studies, (b) stimulation and release of endogenous insulin through direct activity on the pancreas, (c) possible regeneration of the pancreas, and (d) slow antidiabetic activity, requiring administration for 6 months to 1 year.

8.2.20 Huckleberry/Bilberry (*Vaccinium myrtillus*)

Bilberry has been used traditionally in the treatment of diabetes, and research suggests that its leaf extract can lower blood sugar levels. Bilberry extract rich in flavonoids exhibited protective effect by scavenging free radicals and attenuating mitochondrial dysfunction in the liver of restraint stressed mice.

8.2.21 Kalmegh or Kalamegha (*Andrographis paniculata*)

Kalmegh has been extensively investigated for its antihyperglycemic and hypoglycemic properties in several animal models and controlled clinical studies. It appears that the water extract does not exert any hypoglycemic effect on nondiabetic animals, whereas the methanolic extract and andrographolide showed reduction in serum glucose of both diabetic and normal laboratory animals. Chronic administration of the extract for 6 weeks showed no effect on fasting blood glucose level but significantly prevented orally administered glucose-induced hyperglycemia in nondiabetic rabbits without affecting epinephrine-induced hyperglycemia. However, in chemically induced diabetic laboratory animals, it significantly reduced serum blood sugar levels. It has been suggested that the hypoglycemic effect of *A. paniculata* may be due to insulin release from pancreatic β-cells through ATP-sensitive potassium channels, similar to other insulinotropic antidiabetic agents. *In vitro* experiments indicate that inhibition of α-glucosidase and α-amylase enzymes could be the mechanism by which the ethanol extract of *A. paniculata* and andrographolide produce the hypoglycemic effect. It is highly possible that the hypoglycemic and antihyperglycemic activities of the extract and andrographolide may involve different mechanisms in normal and diabetic conditions. Water extract seems to be a more suitable candidate for use as dietary supplement as it does not affect fasting blood glucose levels of nondiabetics.

Andrographis is a major ingredient in the detoxifying bitters developed by Intercedd Health Products, called Uptimax Bitters-IHP™.

8.2.22 Houpu Magnolia (*Magnolia officinalis*)

The plant is used in traditional Chinese medicine for the management of diabetes and related diseases. A bioactive compound magnoline has been isolated from the bark of houpu magnolia and shown to be responsible for the use of the herb in the management of diabetes and MetS. Clinical studies support the use of magnolol (*Magnolia officinalis*) for blood glucose control and to prevent or slow down the development of complications such as diabetic nephropathy. Magnolia can regulate adrenal stress hormones such as dehydroepiandrosterone and cortisol, which can be imbalanced in the diabetic state and in MetS. The plant is often used in conjunction with *Phellodendron amurense*.

8.2.23 Mucuna Beans, Velvet Bean (*Mucuna pruriens*)

Mucuna is minor crop cultivated in West Africa for its edible seeds used as a food thickener and medicinal agent for the treatment of a variety of diseases, including male sexual dysfunction. The seed pods are covered by orange hair-like needles that are readily dislodged to cause itching and dermatitis. The chemical compounds responsible for the itch are a protein, mucunain, and serotonin. The plant is rich in L-dopa and the seed powder of *Mucuna pruriens* has been clinically assessed in several studies for its application in the treatment of Parkinson's disease. The antidiabetic properties of Mucuna have been confirmed by the analyses of the alcoholic extract against laboratory-induced hyperglycemia.

8.2.24 Ogbono–Dika Fat (*Irvingia gabonensis*)

Seeds of *Irvingia* species are used in West African culinary arts as a mucilaginous soup thickener for the preparation of "Ogbono" soup. The aqueous extract has been found by laboratory studies and clinical outcome studies to have a beneficial effect on the management of type 2 diabetes.

In high-fat-diet rats, the mucilage was effective in preventing increase in plasma lipid levels, improving the antioxidant enzyme levels, exerting beneficial effects on lipid metabolism, and avoiding large increase in food intake and body weight. This is due to the effect the mucilage exerts on intestinal peptide involved in the regulation of food intake, and also their gel-forming and good antioxidant properties. A proprietary formulation of *Irvingia* extract, Evira-IHP™ is marketed by Intercedd Health Products as an antiobesity supplement.

8.2.25 Onion (*Allium cepa*)

Onions, especially the red variety, have activities similar to those of garlic. Red onion seeds contain higher amounts of oil, crude protein, copper, and zinc, and lower amounts of sodium than other typical spices, along with phytochemicals such as sulfur-containing flavor compounds able to improve glycemic control, delay oxidation damage, down-regulate inflammatory cytokines, enhance anticoagulant activity, induce adipose tissue cell death, and steroidal saponins with hypocholesterolemic, antidiabetic, antitumor, and antitussive activities.

8.2.26 Okra (*Abelmoschus esculentus*)

Okra is valued in the folk management of duodenal ulcers and diabetes. The glycosylated molecules found in the okra mucilage have been related to the inhibition of adhesion of *Helicobacter pylori* to human gastric mucosa. Such molecules could also contribute to glucose entrapment and α-glucosidase inhibition that might be advantageous in the management of diabetes. The fruit and the leaves have antioxidant properties. It has been observed that the distribution of phenolics in methanolic extracts of okra correlates with distribution of antioxidant activity and its antidiabetic properties.

8.2.27 Plantain (*Musa paradisiaca*)

Plantain (*Musa paradisiaca*) and banana (*Musa sapientum*) are monocotyledonous, triploid perennial, succulent crops belonging to the family Musaceae. Morphologically, the two crops can be distinguished only at the fruiting stage, at which plantains produce longer and more starchy fruits against the sweet and smaller bananas. Plantains are widely used as a vegetable in many recipes whereas bananas can be eaten as fruits and taste different at every stage of development. Unripe plantains are used either alone or in combination with cocoyam (*Colocasia esculenta*) as flour in the preparation of carbohydrate meals for diabetics. The undifferentiated slim, tubular and white-colored clusters found to be present inside the heart-shaped male flowers, called "tepals," are used in traditional medicine for the treatment of many diseases, including ulcer, urolithiasis, gastrointestinal disorders, and diabetes. Laboratory studies have shown that plantain tepals possess antidiabetic activity against drug-induced hyperglycemia. Plantains are therefore valuable nutraceuticals in both dietary control of diabetes and as a dietary supplement in the management of type 2 diabetes.

8.2.28 Prickly Pear Cactus (*Opuntia streptacantha*)

The prickly pear cactus has been used in South American traditional medicine as an effective antidiabetic herb. In Mexico, cactus capsules are sold in herbal shops and dietary supplement outlets for the management of blood glucose. Animal studies and short-term human clinical trials indicate that the plant possesses antidiabetic properties.

8.2.29 Scent Leaf (*Ocimum gratissimum*)

Ocimum species are used as vegetable spices in soups and in traditional medicine for the treatment of various diseases. *Ocimum gratissimum* L. is popularly used to treat diabetes mellitus. The hypoglycemic activity of this medicinal species has been confirmed by several *in vivo* studies. The plant contains several volatile components, including the hypoglycemic phenolic substances such as L-caftaric acid, L-chicoric acid, eugenyl-β-D-glucopyranoside, and vicenin. The activity of *O. gratissimum* decoction fractions has been shown by laboratory studies to be mainly due to the presence of chicoric acid. A hypoglycemic tetracyclic triterpene has also been isolated from the related *Ocimum sanctum* from India.

Scent leaf is a major ingredient in the antidiabetic tea Vernonia-Ocimum™ marketed by Intercedd Health Products.

8.2.30 Soursop (*Annona muricata*)

Soursop fruit and leaf extracts have shown demonstrable antidiabetic activities in laboratory and human subjects. It has been shown that the extract displayed significant reduction of oxidative stress of pancreatic β-cells of streptozotocin-induced diabetic rats, which was confirmed by an increase in insulin immunoreactive β-cells and protection against degeneration of β-cells. The plant extract was not effective in normal rats. In diabetic rats, a single administration of the extract significantly reduced blood glucose levels by 75% and 58.22%, respectively, at a dose of 100 mg/kg and 200 mg/kg as compared to the initial value. Treatment of normal rats 3 days prior to diabetes induction showed that *Annona muricata* extract has no effect within 72 h following STZ injection. However, 14 days post-treatment, the extract at the dose of 100 mg/kg significantly reduced blood glucose levels as compared with initial value and diabetic control rats.

8.2.31 Soybeans (*Glycine max*)

Several studies in humans and animals suggest that soy has beneficial effects in patients with diabetes mellitus. When soy flour was added to whole-durum meal in alloxan-diabetic hypercholesterolemic rats, the flour, with or without methionine, lowered the elevated plasma glucose, cholesterol, and lipid concentrations. In a comparative study with a diet containing a mixture of animal and plant protein, and a diet containing soy protein, the latter reduced the frequency and delayed the onset of diabetes. This finding suggests that the development of type 2 diabetes depends on the nature of the dietary protein. Fermented unsalted soybeans have also been shown to possess insulin mimetic activity. It was found that in 90% pancreatectomized diabetic Px rats the soy diet supplementation for 8 weeks enhanced insulin secretion. It also elevated pancreatic β-cell hyperplasia by increasing its proliferation and decreasing apoptosis.

8.2.32 Tea (*Camellia sinensis*)

Tea is one of the most widely consumed beverages in the world. Its medicinal effects have a history dating back almost 5000 years. Tea, especially green tea, contains several biologically active molecules, including flavonoids, polyphenols, caffeine, and amino acids. Tea flavonoids reduce inflammation, have antimicrobial effects, and prevent tooth decay. Consumption of tea may have diuretic effects due to caffeine. A related compound found in tea is theophylline, a licensed medicine for the treatment of respiratory diseases such as asthma. Various tea types have been shown to be useful in the management of diabetes, an activity believed to be due to the many polyphenols it elaborates.

8.2.33 Turmeric (*Curcuma longa*)

The rhizome of the culinary herb turmeric (*Curcuma longa*) contains curcuminoids, which are known to possess antioxidants, anticancer, and anti-inflammatory properties. Extracts of the rhizome exhibit strong antidiabetic activities in several experimental models. One of the constituents, bisdemethoxycurcumin (BDMC) has been found to be the inhibitor to inactivate human pancreatic α-amylase (HPA), a therapeutic target for oral hypoglycemic agents in type 2 diabetes. Turmeric is a good functional food for controlling starch digestion in order to reduce postprandial hyperglycemia. BDMC itself is being developed as a drug candidate against inhibitors of HPA in diabetes management.

8.3 Fiber-Rich Diets in the Prevention of Diabetes and Obesity

It has been established that the type and amount of dietary fiber consumed play an important role in diabetes management, improving insulin sensitivity, decreasing body weight gain, and reducing the risk factors of cardiovascular disease. Fiber-rich diets have been shown by empirical studies to protect an organism against obesity and diabetes but the mechanisms involved were not well understood until recently. Scientists believe that the mechanism involves the intestinal flora and the ability of the intestine to produce glucose between meals. In an investigation by a French-Swedish team including researchers from CNRS, Inserm, and the Université Claude Bernard Lyon 1 (Unité Inserm 855 "Nutrition et Cerveau") published in the journal *Cell*,[6] it was established that the fiber-rich diets modulate the role of the intestine and its associated microorganisms in maintaining glycemia. It is highly recommended that fiber-rich diets be part of the measures to prevent diabetes and obesity.

Scientists have long known that most fibrous fruits and many vegetables such as edible grasses, salsify, cabbage, or beans are rich in so-called fermentable fibers. Such fibers cannot be digested directly by the intestine but are instead fermented by intestinal bacteria into short-chain fatty acids such as propionate and butyrate, which can in fact be assimilated by our bodies. The protective effect of these fibers is well known to researchers: animals fed a fiber-rich diet become less fat and are less likely to develop diabetes than animals fed a fiber-free diet.

It is noteworthy that the intestine is in fact capable of synthesizing this sugar and releasing it into the bloodstream between meals and at night. However, glucose has particular properties: it is detected by the nerves in the walls of the portal vein (which collects the blood coming from the intestine), which in turn sends a nerve signal to the brain.

In response, the brain triggers a range of protective effects against diabetes and obesity: the sensation of hunger fades, energy expenditure at rest is enhanced, and, last but not least, the liver produces less glucose.

In laboratory studies, when rats and mice were subjected to diets enriched with fermentable fibers, or with propionate or butyrate, it was observed that there was a strong induction of the expression of genes and enzymes responsible for the synthesis of glucose in the intestine. It was found that the intestine of these animals used propionate as a precursor to increase the production of glucose. Mice fed a fat- and sugar-rich diet supplemented with fibers became less fat than control mice and were also protected against the development of diabetes, thanks to significantly increased sensitivity to insulin.

In a repeat experiment, no protective effect was observed in mice whose intestinal ability to produce glucose had been suppressed by genetic engineering. The mice in the repeat experiment became fat and developed diabetes like those fed a fiber-free diet. It is therefore the production of glucose by the intestine from propionate and butyrate that catalyzed the positive effects of fermentable fibers on the organism. A prospective human study of a large population in Taiwan analyzed the information on dietary and biochemical profiles and at least one additional follow-up visit on a total of 1604 healthy subjects aged 30 years and above. The study established that people who consume fiber-rich diets had a lower incidence of diabetes. It was also found that lower magnesium, lower total dietary fiber intake, or lower intake of both was associated with higher risk of diabetes.

8.4 Polyherbal Formulations

8.4.1 Immunovit-IHP™

The dietary supplement Immunovit-IHP is indicated as a general detoxifier and immune system booster. It has been shown to be valuable in the management of chronic diseases, including diabetes. The primary active ingredient of Immunovit-IHP is the Asian mushroom, *Ganoderma lucidum*, also called "Reishi." The major constituents include *Ganoderma* triterpenoids and polysaccharides, which are unique to Reishi and not found in significant quantities in other plants. Over 150 triterpenoids are found in *G. lucidum*, which are responsible for some of the numerous pharmacological effects associated with the mushroom. The second component of Immunovit-IHP is dried extract of the fruits of *Punica granatum*, which retains the polyphenols that prevent the harmful effects of singlet oxygen and other proinflammatory free radicals that cause tissue damage in diabetes. The formulation also contains aged Korean ginseng, *Panax ginseng*, an adaptogen with a broad spectrum of beneficial activities, including detoxification, cardiotonic health, and stress reduction.

The individual components of Immunovit are known to be effective in the reduction of fasting blood glucose level and amelioration of the complications of diabetes. In combination, they have been shown to work synergistically in the management of diabetes. One of the polysaccharides (PSG-1) found in *Ganoderma* when administered orally for 4 weeks significantly reduced levels of fasting blood glucose, improved endothelium-dependent aortic relaxation, increased levels of PI3K, phospho-Akt (p-Akt), endothelial nitric oxide synthase (eNOS), and nitric oxide in the aorta from diabetic rats, compared to untreated diabetics.

Immunovit-IHP is particularly useful in the management of diabetes because of its generalized activity against associated metabolic disorders, or the so-called MetS. As mentioned earlier, MetS, also known as insulin resistance syndrome or syndrome X, is the

name of a group of risk factors that commonly occur together and include hypertension, abdominal obesity, dyslipidemia, and dysglycemia. The use of Immunovit is likely to reduce the risk for the chronic comorbidities, particularly cardiovascular disease, diabetes, and nonalcoholic fatty liver disease that often occur with elevated blood sugar.

8.4.2 Physogen and Physogen Plus

Physogen is a proprietary tea formulation that contains bitter kola (*Garcinia kola*), utazi (*Gongronema latifolium*), and bitter leaf (*Vernonia amygdalina*), while Physogen Plus has the three ingredients listed above and the scent leaf (*Ocimum gratissimum*). The antidiabetic properties of the individual constituents have been discussed earlier. The combination of these known antidiabetic ingredients exploits the synergy inherent in their multiple mechanisms of action.

8.4.3 Ohsu-IHP

The major constituents of Ohsu-IHP is the extract of the king tuber mushroom, *Pleurotus tuber-regium*. It is a basidiomycete that forms a large spherical to ovoid, subterranean sclerotium, composed of fungus tissue, sometimes up to 30 cm or more in diameter. It is used in Nigeria as a soup thickener. In this formulation, Intercedd incorporated the processed polysaccharides into an oral dietary supplement, which has been shown to be effective in the management of diabetes.

8.4.4 Vernonia-Ocimum Tea

The formulation combines the activities of these two well-known culinary herbs. It is especially useful as a preventive tea for prediabetics and for the management of type 2 diabetes. The prebiotic properties of the formulation are valuable in restoring the integrity of the intestinal biota, which often play a modulating role in intestinal glucose uptake.

8.4.5 Glucosol™

This is a single herb formulation that contains an extract from the leaves of *Lagerstroemia speciosa* standardized to 1% corosolic acid. It has been demonstrated to be an effective antidiabetic agent in a randomized clinical trial involving type 2 diabetics (non-insulin-dependent diabetes mellitus, NIDDM). Subjects received a daily oral dose of Glucosol, and blood glucose levels were measured. Glucosol at daily dosages of 32 and 48 mg for 2 weeks showed a significant reduction in the blood glucose levels. Glucosol in a soft gel capsule formulation showed a 30% decrease in blood glucose levels compared to a 20% drop seen with dry-powder-filled hard gelatin capsule formulation ($P < 0.001$), suggesting that the soft gel formulation has a better bioavailability than a dry powder formulation.

8.5 Problem with Sugars: Health Implications of High-Fructose Corn Syrup

There has been a worldwide increase in the rate of the incidence of obesity, T2DM, and MetS. So many reasons have been put forward to explain this scourge, which is assuming

epidemic proportions throughout the world. Several studies have implicated increased consumption of calorie-rich/high-fat diet, lack of exercise, and sedentary lifestyles as some of the likely causes. But some scientists argue that increased consumption of a carbohydrate-rich diet in the form of enhanced contents of sucrose, fructose, or glucose, or a combination of all three in ready-to-eat foods is responsible for the increasing incidence of obesity, T2DM, and MetS.

In the United States, the report of the first National Health and Nutrition Examination Survey (NHANES) and its follow-up studies indicated that although the U.S. population has increased its proportion of energy consumption from carbohydrates and decreased its proportion from total fat, an increase in obesity was still observed.[7] This finding implies that obesity may correlate better with sugar rather than with fat consumption, and that reducing fat consumption while increasing sugar consumption actually increases the level of obesity.[8] The increase in sugar consumption is believed to be due to increased use of fructose and especially the substitution of sucrose with high-fructose corn syrup (HFCS).

HFCS, also known as glucose–fructose, isoglucose, and glucose–fructose syrup, is a sweetener produced by an "acid-enzyme" process from corn starch solution. It involves the acidification of corn starch, which begins the process of breaking up the existing carbohydrates, and then enzymes are added (usually glucose isomerase) to further metabolize the starch and convert most of the resulting sugars to fructose. HFCS was first marketed in the early 1970s by the Clinton Corn Processing Company, together with the Japanese research institute where the enzyme was discovered. HFCS has become the preferred sweetener among most food manufacturers and it is found in confectioneries, baked foods, juices, and virtually in almost every processed food. The food industry claims that HFCS is similar to sucrose, since both HFCS and sucrose contain glucose and fructose. However, there are at least two clear differences between them. First, sucrose is composed of equal amounts of the two simple sugars (i.e., 50% fructose and 50% glucose) but the typical high-fructose corn syrup (HFCS-55) features an imbalanced ratio, containing 55% fructose and 42% glucose. Larger sugar molecules called higher saccharides (oligomers) make up the remaining 3% of the sweetener. Other varieties of HFCS available commercially are HFCS-42 and HFCS-90 (the numbers reflect the percentage of fructose they contain).

Second, as a result of the manufacturing process for HFCS, the fructose molecules in the sweetener are free and unbound, ready for absorption and utilization. In contrast, every fructose molecule in sucrose that comes from cane sugar or beet sugar is bound to a corresponding glucose molecule and must go through an extra metabolic step before it can be utilized. Third, the two components of sucrose are metabolized differently (Figure 8.1). Metabolism, the sum of all chemical reactions that take place within a cell or organism, is the crucial unresolved issue concerning the high consumption of fructose and HFCS. The sheer quantity of fructose consumed daily through HFCS distorts the normal sugar metabolism, as the Renaissance physician Paracelsus famously said, "The dose makes the poison." The World Health Organization has recommended that people limit their consumption of added sugars to 10% of calories, but experts say that typical consumption of empty calories in the United States is nearly twice that level and people of African descent have an even lower tolerance level for fructose.

It was previously believed that because both glucose and fructose give the same number of calories per gram that they could be interconverted and utilized similarly instantly in the cells. But this is not the case. It has long been established that fructose and glucose are metabolized differently in the liver because the liver does not contain hexokinase, which is needed to convert phosphorylate fructose to fructose-6-phosphate.[9] In all other cells, however, fructose and glucose are interchanged quite rapidly.[10] Glucose can be phosphorylated

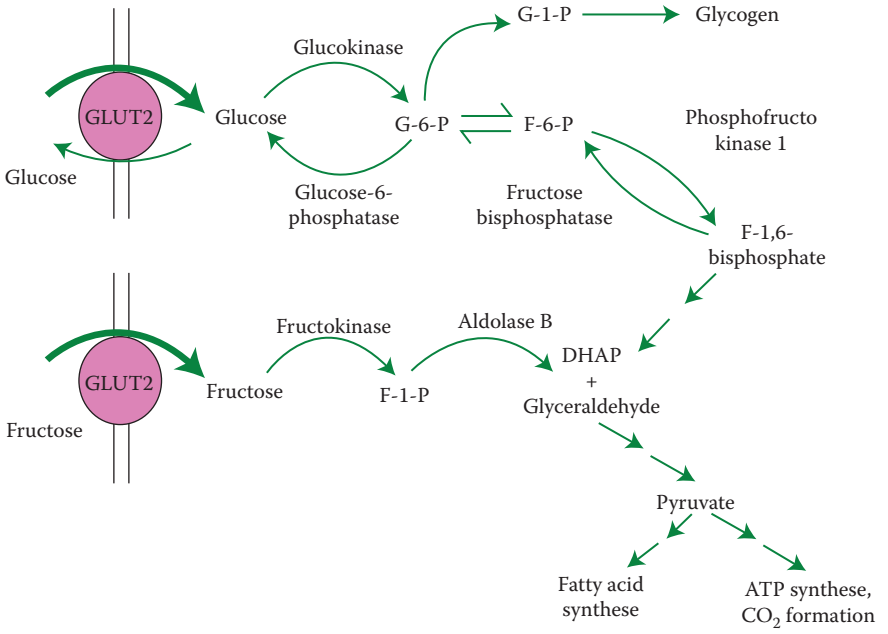


FIGURE 8.1
Scheme showing differences in the metabolism of glucose and fructose by the liver. ATP, adenosine triphosphate; DHAP, dihydroxyacetone phosphate. (Reprinted from *Nutrition*, vol. 31, Das, U. N., Sucrose, fructose, glucose, and their link to metabolic syndrome and cancer, 249–257, 2015, with permission from Elsevier. http://dx.doi. org/10.1016/j.nut.2014.05.015. Accessed December 2015.)

in the liver by glucokinase to glucose-6-phosphate. Glucose-6-phosphate is then converted to fructose-6-phosphate that, in turn, is phosphorylated by phosphofructokinase (PFK) to glucose-1-6-phosphate, which is the ultimate gatekeeper for entering glycolysis. In comparison, fructose that enters the liver is phosphorylated by fructokinase (also called ketohexokinase) to make fructose-1-phosphate rather than fructose-6-phosphate. Thus, the liver is unique in regard to its ability to differentially metabolize glucose and fructose. Thus, the glucose that enters the cell is phosphorylated and gets stored as glycogen or exits the cell (Figure 8.1). In the liver, however, fructose bypasses that whole machinery because it does not need PFK. Fructose gets phosphorylated to form fructose-1-phosphate and, as a consequence, becomes a substrate for aldolase, thus producing higher levels of ATP and citrate, which results in the synthesis of fatty acids.[11] Thus, most, if not all, of the fructose that is consumed gets converted to fat.

In addition to these differences, HFCS contains reactive dicarbonyl compounds that are created during the processing steps. These dicarbonyl compounds can in turn create advanced glycation end-products, with potential adverse health effects. The major concern is that there is growing evidence regarding the health risk associated with the consumption of HFCS. The sweetener has been linked to metabolic diseases such as obesity and diabetes, and cancer. In February 2010, scientists at Princeton University published a report on the effect of HFCS on rats and concluded that "in addition to causing significant weight gain in lab animals, long-term consumption of HFCS also led to abnormal increases in body fat, especially in the abdomen, and a rise in circulating blood fats called triglycerides."[12] The researchers say the work sheds light on the factors contributing to obesity trends in the United States. In an interview, one of the scientists, Professor

Bart Hoebel, who specializes in the neuroscience of appetite, weight, and sugar addiction, stated: "When rats are drinking HFCS at levels well below those in soda pop, they're becoming obese—every single one, across the board. Even when rats are fed a high-fat diet, you don't see this; they don't all gain extra weight."[12]

However, the issue still remains controversial as a 2002 study conducted by the U.S. National Academy of Sciences concluded that "there is no clear and consistent association between increased intakes of added sugars and BMI [body mass index]," and that because of discrepancies in data from different studies, it could not set a tolerable upper intake level. Even the prestigious Mayo Clinic in America maintains that "Research has shown that HFCS is chemically similar to table sugar. Controversy exists, however, about whether the body handles HFCS differently than table sugar."[13] Added sugar, especially HFCS, is not easy to track in foods as it is almost everywhere. It is in soft drinks, candies, ice creams, and desserts and is also added to a wide range of non-sweet items such as cereals, potato chips, peanut butter, and soup.

8.5.1 Fructose and Cancer

Studies have shown that high fructose intake is associated with increased risk for cancer by producing a significant increase in the activities of the enzymes glucose-6-phosphatase, 6-phosphoglucose dehydrogenase, 6-phosphogluconate dehydrogenase, 6-phosphoglucose isomerase, aldolase, α-glycerophosphate dehydrogenase, 3-phosphoglyceraldehyde dehydrogenase, 3-phosphoglycerate kinase, and lactate dehydrogenase,[14] enhancing c-myc expression,[15] augmenting inflammation, interfering with the metabolism of EFAs, and suppressing the formation of anti-inflammatory bioactive lipids, lipoxins, resolvins, and protectins. Fructose and, to some extent, glucose promote flux through the pentose phosphate-enhancing protein synthesis and thus indirectly increase tumor growth. Fructose treatment also may be associated with more aggressive cancer behavior and may promote metastasis. Thus, glucose favors overall growth kinetics, whereas fructose promotes the development of obesity, T2DM, and MetS and a more aggressive cancer phenotype. Fructose has become ubiquitous in the food supply, and the largest groups of consumers are teens and young adults. Therefore, understanding the potential health consequences of fructose and its role in the development of chronic disease is critical.

8.5.2 Fructose and Hypertension

The metabolism of fructose in the liver involves its conversion to fructose-1-phosphate by the enzyme fructokinase.[16] This is an adenosine triphosphate-requiring reaction,[17] depleting available intracellular phosphate. Phosphorylation of this large substrate load leads to activation of the scavenger enzyme adenosine monophosphate deaminase-1, which recoups intracellular phosphate by converting the adenosine phosphate breakdown products (adenosine diphosphate, adenosine monophosphate, and inosine monophosphate) to the cellular waste product uric acid.[18] Buildup of urate in the circulation inhibits eNOS, resulting in decreased nitric oxide in the vasculature. Nitric oxide is an endogenous vascular smooth muscle relaxant; its depletion by urate results in hypertension.[19]

Rodent models demonstrate that a high-fructose diet leads to hypertension and renovascular damage.[20] Recently, sugar consumption has been correlated with uric acid concentrations in American adults.[21] The soft drink consumption in adolescents in the

recent National Health and Nutrition Examination Survey (NHANES) evaluation demonstrates a positive relationship with uric acid levels and with systolic hypertension.[22] It has also been found that concurrent soft drink consumption and caffeine ingestion further complicates the correlation between added sugar in soft drinks and blood pressure elevation in adolescents.[23]

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9

Dietary Supplements in Cancer Prevention and Management

9.1 Introduction

The term "cancer" applies to a large group of diseases characterized by an uncontrolled proliferation of abnormal cells that can affect any part of the body, including circulatory, lymphatic, digestive, urinary, and reproductive systems, as well as the skin and blood.[1] Cancer is the fastest-growing disease, worldwide. Moreover, according to the World Health Organization, cancer is one of the leading causes of morbidity and mortality worldwide, with approximately 14 million new cases and 8.2 million cancer-related deaths in 2012. The number of new cases is expected to rise by about 70% over the next two decades. The five most common sites of cancer diagnosed among men in 2012 were lung, prostate, colorectum, stomach, and liver, whereas among women, the five most common sites diagnosed were breast, colorectum, lung, cervix, and stomach. More than 60% of world's total new annual cases occur in Africa, Asia, and Central and South America. These regions account for 70% of the world's cancer deaths.[2]

Cancer occurs as the outcome of a carcinogenesis process that involves three distinguishable but closely connected stages: (a) initiation stage, which is the outcome of a rather rapid and irreversible outcome of assault on a normal cell, leading to a transformed or initiated cell, (b) promotion phase, in which the initiated cell changes to a preneoplastic cell, and (c) the progression stage during which the preneoplastic cell becomes a neoplastic cell. Cancer therefore arises from one single cell. The crucial initiation phase may be due to the initial uptake of a carcinogen and the subsequent stable genotoxic damage caused by its metabolic activation. Other causes of cancer initiation include oxidative stress, chronic inflammation, and hormonal imbalance.[3] The WHO has identified these changes as the result of the interaction between a person's genetic factors and three categories of external agents, including

- Physical carcinogens, such as ultraviolet and ionizing radiation
- Chemical carcinogens, such as asbestos, components of tobacco smoke, aflatoxin (a food contaminant), and arsenic (a drinking water contaminant)
- Biological carcinogens, such as infections from certain viruses, bacteria, or parasites

Perhaps beyond the initiation, promotion, and progression stages of cancer is the metastasis phase during which the cancerous cells invade other otherwise healthy cells, tissues, and organs with the help of adhesion molecules and angiogenic factors. Cancers

can therefore be considered as attempts by cells to adapt to a changing environment. Countries undergoing nutritional transition from traditional high-vegetable, low-fat diets to processed high-fat, high-animal protein, and chemical-laden Western diets may be more vulnerable to noncommunicable diseases, including cancers. The introduction of novel food chemicals, preservatives, and additives will exert additional stress in the normal functioning of the cells. It has been suggested that the growth of powerful economic institutions and globalization is accelerating, mixing many cancer risk factors, and generating new cancer risk factors.[4] Dr. Annie Sasco of Bourdeux University, France argues that concurrent with globalization are apparent risk factors such as modern diet, addictive products, pharmaceuticals, and toxic and waste products, which must be factored into cancer prevention and treatment programs.[4]

It is estimated that up to 40% of all cancers can be prevented by a healthy lifestyle such as appropriate diet, physical activity, and maintenance of appropriate weight.[5] The clinical evidence in support of this assertion using current epidemiological methods remains ambiguous.[6] Two major studies on the relationship between plant food intake and cancer produced conflicting results. The original report of the World Cancer Research Fund (WCRF)/American Institute for Cancer Research (AICR) showed that increased consumption of vegetables and fruit was likely to be protective against cancer at many organ sites.[7] But a large prospective study by the European Prospective Investigation into Cancer and Nutrition (EPIC) could not find any clear association between fruit and vegetable intake and the occurrence of cancer at many of the same organ sites.[8] Given the complexity of cancers and the enormous variations that are possible in what constitutes "food," the controversy regarding the relationship between the consumption of fruits and vegetables and cancer will not be definitively resolved anytime soon. However, a more pragmatic approach is that proposed by Thompson[6] which focused on a "pharmacology analogy" that viewed food as drug delivery vehicles. This approach fits well into the "functional food" concept. The general understanding in the functional food approach is not to portray foods as medicines, but rather to identify the underlying nature of the science that drives current efforts to discover how vegetable and fruit intake is associated with cancer incidence and cancer mortality. While the individual bioactive molecules identified as possible anticancer drugs from vegetable sources will be discussed, the intent is not to present such culinary plants as pharmaceuticals or their constituents as "active molecules" but as "nutraceuticals" that confer "functional" roles on vegetables, fruits, seeds, and roots in the management of cancer. Furthermore, this approach accommodates the contribution of the complex synergistic interaction of various constituents of anticancer herbs.

Indeed, many therapeutic agents have been developed from plants both for cancer treatment and for chemoprevention of the initiation phase, suppression of preneoplastic cells, and formation of neoplasmic cells. The advent of modern cancer chemotherapy can be traced back to the isolation of vinblastine and vincristine from the African periwinkle, *Catharanthus roseus* G. Don. The two drugs have been used in clinical oncology for almost 50 years. The alkaloids exert their anticancer property by blocking the polymerization of tubulin molecules into microtubules, preventing the formation of the mitotic spindle, which results in metaphase arrest and apoptosis.[9] A series of semisynthetic analogs of these two important drug molecules have been developed aimed at improving the activity and pharmacokinetics of the original compounds.[10] Other plant-derived compounds have been developed as clinically useful chemotherapeutic agents. Four structural types of anticancer compounds are discernible, namely, vinca alkaloids, epipodophyllotoxin lignans, taxane diterpenoids, and camptothecin quinoline alkaloid derivatives. These substances embrace some of the most exciting new chemotherapeutic agents currently available for

use in a clinical setting. These include vinblastine, vincristine, paclitaxel (Taxol®), and the camptothecin derivatives, topotecan and irinotecan, etoposide, and epipodophyllotoxin.

Most of the available drugs for the treatment of cancer, however, are very toxic with serious side effects that limit their therapeutic application. Sometimes, such treatments are supplemented with radiation therapies whose side effects are also well known. There has therefore been a global effort to search for novel bioactive compounds that will be able to selectively and safely prevent and treat cancers. The highly successful global program coordinated and financed by the National Cancer Institute of the National Institutes of Health of the United States is worthy of special mention. Several thousands of substances, including phytochemicals and extracts of medicinal plants, have been screened for their ability to kill cancer cells and prevent the development of tumors.[11] It is estimated that compounds isolated from natural products have contributed to the discovery and development of over 60% of the anticancer drugs currently in regular use, or undergoing clinical study.[12]

The traditional uses of medicinal plants for the treatment of diseases, including cancer, have been of tremendous help to drug discovery programs in the selection of plants for investigation as a source of novel, bioactive natural products. However, only a small fraction of the several thousands of compounds identified from *in vitro* and animal studies have shown promise as candidates for drug development. This lack of translation of laboratory studies to useful clinically relevant drugs is due to the misconception that therapeutic response can only be achieved through the classical pharmacological drug–target interaction model. The approach adopted in this book is not to attempt a Procrustes fit of African functional foods with claimed therapeutic value into the reductionist model of modern pharmacology. Rather, examples are provided to illustrate the richness of the African cuisine as sources of possible anticancer remedies. Their chemical composition and reported biological activities will be used as indicative of possible evidence to support their application.

Several phytochemicals from many African foods, herbs, and spices have been shown to act at various stages of cancer development by inhibition of initiation and promotion of carcinogenesis, induction of tumor cell differentiation and apoptosis, and suppression of tumor angiogenesis.[13] The major functional foods with anticancer properties and their constituents are outlined below. Their mechanism of action and other details are given in the next section of the book under the relevant pharmacognostical profile.

9.2 Functional Foods with Chemoprotective Properties

1. *Aloe* spp.
2. Carrots
3. Turmeric
4. Garlic
5. Bitter leaf (*Vernonia amygdalina*)
6. Corn (*Zea mays*)
7. Lemongrass
8. Tomato

9. Green tea
10. Bitter kola
11. Rooibos tea
12. Kola nuts
13. Ginger
14. Palm oil
15. Cocoa polyphenols
16. *Tetracarpidium*
17. Green coffee
18. Peppers
19. Onions
20. Leafy vegetables
21. Fruits
22. Spices

9.3 Aloin and Related *Aloe* Compounds

Aloin is an anthraquinone glycoside found in members of the genus *Aloe* (family Liliaceae). Most of *Aloe* species are indigenous to Africa, but now have wide distribution in the tropical and subtropical regions of the world. Two species, *Aloe ferox* and *Aloe vera* (*A. barbadensis*), are used extensively in traditional medicine in Africa, Asia, and Europe. *Aloe vera* is one of the most popular botanicals used in medicine, dietary supplements, and cosmetics. The most important active constituents of the *Aloe* plants are anthraquinones such as aloin, barbalion, anthranol, cinnamic acid, aloetic acid, emodin, chrysophanic acid, resistanol, and enzymes (including cyclooxygenase and bradykinase), as well as other compounds such as vitamins, saccharides, and amino acids. The best-known constituent, however, is aloin (1,8-dihydroxy-10-(β-D-glucopyranosyl)-3-(hydroxymethyl)-9(10H)-anthracenone, 10-β-D-Glucopyranosyl-1,8-dihydroxy-3-(hydroxymethyl)-9(10H)-anthracenone), also known as Barbaloin.

Aloin is a bitter-tasting yellow crystal and is a C-glycoside derivative of anthraquinone. Although the C-glycoside side chain of aloin is not easily hydrolyzed *in vitro*, orally administered aloin is known to be hydrolyzed by esterases secreted by intestinal microflora. Once the C-glycoside is hydrolyzed, it forms aloe emodin anthrone, which is further autooxidized to the quinone aloe emodin.[14]

Both *Aloe* species have been used for the treatment of different types of cancer. Several studies have reported the anticancer properties of *Aloe vera* gel (AVG).[15] These include studies on smoking and lung cancer, which showed that AVG can prevent pulmonary carcinogenesis and cancer of other tissues; inhibit against Ehrlich ascite carcinoma cell number in acute myeloid leukemia and acute lymphocytic leukemia, with concentration-dependent cytotoxicity effect; be active against two cell lines of colon (DLD-1 and HT2); and that *Aloe* polysaccharides exhibited anticancer effects by stimulating immune response through activation of macrophages.

It has been shown that aloe emodin possesses selective activity against neuroectodermal tumors, without any adverse effect on normal cells. It promotes cell death through

specific drug uptake by neuroectodermal tumors. In another study, it was found that aloe emodin had an inhibitory effect on the activation of the Epstein–Barr virus (which plays a role in the emergence of cancer). The combined effect of aloe emodin and the chemotherapeutic agent cisplatinol (doxorubicin, 5-fluorouracil) on the proliferation of an adhering variant cell line of Merkel cell carcinoma has also been demonstrated.[16] When evaluated on cell viability using Jurkat T cells, treatment with aloin showed a reduction in cell size, compromised membrane integrity, and loss of mitochondrial membrane potential in a dose-dependent manner. It also showed an alteration of the cell cycle, with the loss of cell membrane integrity being preceded by a loss of mitochondrial membrane potential, indicative of a mitochondrial-dependent pathway for aloin-induced apoptosis.[15] *Aloe* extracts have been shown to induce cytotoxic and genotoxic activities on human hepatocellular carcinoma (HepG2) cells through the induction of an apoptotic pathway. Aloe emodin can also promote the macrophage differentiation of U937 cells, suggesting that this anthraquinone could be a potential candidate as a differentiation-inducing selective agent for the therapeutic treatment of leukemia.[17] The combination of aloe emodin with honey has been found to be beneficial in cancer treatment without any observable side effects.[18]

9.4 Green Tea

The leaves of *Camellia sinensi*s or the tea plant produces one of the most popular beverages consumed, worldwide. Tea can be classified into three major commercial types according to the level of fermentation: green tea (nonfermented), oolong tea (half fermented), and black tea (fermented). Green tea contains a much higher level of polyphenols known as catechins, which have been shown to have antimutagenic, antigenotoxic, and anticarcinogenic activities.[19] Green tea contains a complex mixture of polyphenols, as well as both condensed and hydrolyzable tannins. Green tea polyphenols (GTPs) are thought to be primarily responsible for the putative cancer-preventive effects of this beverage. GTPs have been shown to exert growth inhibitory properties against many different types of cancers. The most abundant polyphenol constituents are gallic acid (GA), (2)-gallocatechin (GC), (1)-catechin (C), (2)-epicatechin (EC), (2)-epigallocatechin (EGC), (2)-epicatechin gallate (ECG), (2)-epigallocatechin gallate (EGCG), *p*-coumaroylquinic acid (CA), and (2)-gallocatechin-3-gallate (GCG).

One of the major polyphenols of green tea, epigallocatechin-3-gallate (EGCG), has been shown by several studies to possess antitumor effects.[20] Laboratory studies as well as human epidemiological data support the possibility that green tea has preventive effects against different types of cancer,[21] especially liver cancer.[22] The result of a meta-analysis that investigated whether an association existed between green tea consumption and the risk for liver cancer in prospective cohort studies in Asian populations showed the preventive effects of green tea intake on the risk for liver cancer in female Asian populations. The study involved nine prospective cohort articles involving 465,274 participants, and 3694 cases of liver cancer from China, Japan, and Singapore were included. The summary relative risk (RR) indicated a significant association between the highest green tea consumption and reduced risk for liver cancer (summary RR, 0.88; 95% confidence interval [CI], 0.81–0.97). However, no statistically significant association was observed when analyzing daily consumption of one cup (summary RR, 0.97; 95% CI, 0.95–1.00). When stratified by sex, the protective effect of green tea consumption on risk for liver cancer was observed

only in the group of women (summary RR, 0.78; 95% CI, 0.64–0.96), but not in men (summary RR, 0.89; 95% CI, 0.79–1.00).[23]

For breast cancer, laboratory studies indicate that green tea powder (0.3% in drinking water) for 17 weeks inhibited tumor growth and reduced invasion in 7,12-dimethylbenz(*a*) anthracene (DMBA)-induced rats.[24] One study found that nude mice injected with MDA-MB-231 breast cancer cells had lower tumor burden when treated for 10 weeks with either GTPs (1% in drinking water) or EGCG (1 mg/mouse/day) compared to controls. This was accompanied by induction of apoptosis and inhibition of cell proliferation. Tamoxifen is commonly used to treat breast cancer, and the combination of GTE (1%) and tamoxifen (10% mg) for 38 weeks decreased breast cancer tumor incidence in C3H/OuJ mice more extensively than either treatment alone.[25]

In prostate cancer, epidemiological evidence has shown positive effects in Chinese and Japanese patients following long-term use of green tea. In one reported clinical study, daily consumption of 600 mg of green tea catechins (GTCs) for 1 year reduced progression to prostate cancer from 30% to 3% in men with high-grade prostate intraepithelial neoplasia.[26] After cessation of treatment, the subjects were followed for another 2 years and those that received the GTCs had a tumor incidence of only 7% whereas the placebo group had a 37% incidence.[27]

Green tea consumption has been shown to have a protective effect against stomach,[28] gastric,[29] and colorectal cancers.[30] A reported case-control study of a Chinese population found that green tea intake was associated with reduced risk of stomach cancer (OR50.71) and that the risk was further decreased in individuals that tended not to reuse tea leaves for tea preparation (p-trend 50.006). However, the relationship between green tea intake and reduced risk of stomach cancer appears to be more effective in women compared to men.[31]

For other types of cancer, evidence provided from human observation and laboratory studies supports the cancer-preventive role of green tea intake against many types of cancer. These include bladder and kidney cancers; thyroid cancer; myeloma, lymphoma, and leukemia; skin cancer; ovarian, uterine, and cervical cancers, and pancreatic cancer.[32] The results of clinical studies have been conflicting and the conflicting results have been attributed to possible differences in bioavailability, lifestyle habits, and severity/stage of cancer. Green tea is generally well tolerated and likely plays a role in cancer prevention and/or supports conventional cancer treatments. Green tea and GTP activity can be considered as complementary to other cancer management medications. It has also been observed that other food components may affect the bioavailability and activity of GTPs. Black pepper, for example, contains bioactive compounds such as piperine, which could enhance the bioavailability of GTPs,[33] whereas other foods such as soy may diminish the anticancer effects of green tea.[34]

9.5 Cocoa Polyphenols

The detailed profile of cocoa (*Theobroma cacao*) is discussed in Section III of this book and other activities are discussed elsewhere in this book. Cocoa polyphenolic compounds have been shown by several investigators to have beneficial effects on cardiovascular risk, including the lowering of blood pressure, in both animal models and clinical trials. In the animal experiments, the consumption of cocoa polyphenols demonstrated not only a reduction in blood pressure but also an increase in the expression of a number of genes

associated with endothelial function, which suggests the potential for an epigenetic effect of polyphenols.[35] Upregulated genes associated with reduced blood pressure acted on endothelial function via increased nitric oxide and prostaglandin production. Cocoa polyphenols, including its flavanols epicatechin, catechin, quercetin, naringenin, luteolin, apigenin, and procyanidins, have recently attracted considerable interest because of their potential ability to act as effective chemopreventive agents. Their antioxidant property can exert a protective effect on cell constituents and thereby limit the risk factor for cancer and other chronic diseases.[36] Laboratory studies have also demonstrated that cocoa phenolic compounds exhibit a variety of potential anti-inflammatory effects in intestinal cells,[37] with possible contribution to their cancer chemopreventive activity. A cocoa-rich diet can prevent the early stages of colorectal cancer (CRC) by reducing oxidative stress and cell proliferation by inducing apoptosis,[38] since it has been established that patients with inflammatory bowel disease (IBD) are at increased risk for developing ulcerative colitis-associated CRC. The interleukin-6 (IL-6)/signal transducer and activator of transcription (STAT)-3 signaling regulate survival and proliferation of intestinal epithelial cells and play an important role in the pathogenesis of IBD and CRC. Cocoa is enriched with polyphenols that are known to possess antioxidant, anti-inflammatory, and antitumor activities.[39]

The antitumor effects and mechanisms of cocoa diet on colitis-associated cancer (CAC) using the azoxymethane/dextran sulfate sodium model, with a particular focus on whether cocoa exerts its anticancer effect through the IL-6/STAT3 pathway has been reported. It was found that cocoa significantly decreased the tumor incidence and size in CAC-induced mice. In addition to inhibiting proliferation of tumor epithelial cells, cocoa suppressed colonic IL-6 expression and subsequently activation of STAT3. This demonstrates that the cocoa diet suppresses CAC tumorigenesis, and its antitumor effect is partly mediated by limiting IL-6/STAT3 activation. In addition, cocoa induces apoptosis by increased expressions of Bax and caspase 3 and decreased Bcl-xl.[40] Other types of cancer that may be managed by the consumption of cocoa polyphenols include lung and thyroid cancers; mammary and pancreatic cancers; prostate cancer; hepatic cancer; and leukemia. Human epidemiological studies and clinical trials, as well as laboratory investigation, have clearly demonstrated that cocoa and its main phenolic components can prevent and/or slow down the initiation–progression of different types of cancers. The available evidence suggests that cocoa polyphenols and some of its composite compounds exhibit cellular mechanisms of action that include the modulation of the redox status and multiple key elements in signal transduction pathways related to cell proliferation, differentiation, apoptosis, inflammation, angiogenesis, and metastasis.[41]

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Section III

Monographs



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10

Monographs of Major African Functional Foods

Introduction

This section contains monographs of 67 African food plants that are of considerable scientific interest based on literature citations as feasible candidates for the development of functional foods and/or possible sources of nutraceuticals. These are edible plants selected for their potential functionality and not necessarily by their ranking in the food table. Almost all of them are native to Africa but a few are naturalized crops that are cultivated and consumed at a significant level in Africa for many years. Some of the plants have been featured in the earlier chapters and the additional information in this section should be taken along with the information provided therein. According to Peters and others,[1] there are about 2155 African plant species that are used as food out of over 50,000 recorded species of African flora. The number of plants selected to be highlighted here represents only a tiny fraction of the food plants used in Africa and still less is the number of culinary plants that are used in traditional medicine, which are cataloged in Chapter 2 (Table 2.1). A review of the commercialized food plants by Van Wyk[2] showed that Africa has made a substantial contribution in the global food base, with 119 species, which compares favorably with estimates of 126 crops for Europe, 68 for Central America, and 97 for South America. The entries are not comprehensive and the objective was not to provide a universal coverage of all edible African plants that contain phytochemicals that may be useful for health optimization.

The arrangement of the monographs lists the plants by their common names to assist in their ease of recognition as food plants, followed by a short overview, and a detailed pharmacognostical profile, which includes botanical names, culinary relevance, ethnomedicinal uses, constituents, and pharmacological studies. The description of the plants has been adapted mainly from three sources: *Handbook of African Medicinal Plants*,[3] the online database on African medicinal plants (PROTA4U),[4] and the *Lost Crops of Africa* (three volumes) published by the U.S. National Academy of Sciences.[5] Readers are encouraged to consult these references for additional information.

Alligator Pepper: Grains of Paradise

Overview

Alligator pepper (*Aframomum melegueta*) is an aromatic plant used as a general tonic in West and Central Africa. The flowers of the herbaceous plant are described as "handsome" aromatic, with an orange-colored lip and a rich pinkish-orange upper part. The fruits contain numerous, small, golden red-brown seeds. It yields a very spicy volatile oil and enjoys a folk reputation as an aphrodisiac agent. The fruits are used in traditional medicine for therapeutic purposes and as a ritual plant to appease the gods. The seeds are used in the food industry as an essence to spirits, wines, and beer. Laboratory studies and clinical outcome evaluation tend to support the use of grains of paradise for sexual dysfunction. The extract of the seeds and rhizome has been shown to have antioxidant and anti-inflammatory activities. The pungent and peppery taste of the seeds is caused by the presence of aromatic ketones, 1-(4-hydroxy-3-methoxyphenyl)-decan-3-one ((6)-paradol), zingiberone, 6-gingerol, and 6-shogaol. Alligator pepper has shown potential as a possible treatment for male erectile dysfunction and premature ejaculation. *Aframomum melegueta* seed enjoys a GRAS classification (substances regarded "generally recognized as safe"), and no side effects have been reported from its consumption or usage over the years. It is relatively easy to cultivate and has been incorporated in many dietary supplements and herbal medicines.

Pharmacognostical Profile

Botanical Name: *Aframomum melegueta* K. Schum.

Synonyms: *Aframomum grana-paradisi* (L.) K. Schum; *Aframomum meleguetella* K. Schum; *Alexis grandiflora* (Sm.) Salisb.; *Alpinia grana-paradisi* (L.) Moon; *Amomum grandiflorum* Sm.; *Amomum grana-paradisi* L.; *Amomum melegueta* Roscoe; *Cardamomum grana-paradisi* (L.) Kuntze; *Cardamomum grandiflorum* (Sm.) Kuntze; *Torymenes officinalis* Salisb.

Family: Zingiberaceae

Related Species: *A. daniellii, A. strobilaceum, A. exscapum, A. korarim*

Common Names: Grains of paradise, guinea grain, alligator pepper, melegueta pepper

Description: *A. melegueta* is an aromatic plant cultivated for its edible spicy fruit. It is a perennial herb growing up to 4 m high. The stem is short, marked with the encircling scars of fallen aerial leaves, and it is highly branched. The lower surface bears the roots, which are adventitious and slender. It yields an aromatic rhizome, which is horizontal and tuberous and bears scaly leaves with occasional buds in axils. The leaves are large, about 30 cm long and 12 cm wide, with close nerves below. They occur in two rows with an open or closed sheath sessile or stalked on the sheath; the blades are usually large with numerous closely parallel pinnate nerves diverging obliquely from the midrib. The bracts are few and about half overlapping. The beautiful aromatic flowers are solitary, borne separately from the leafy stem. The fruits are fleshy and indehiscent, and contain numerous small seeds embedded in pleasant-tasting aril. The seeds are golden or red-brown when fresh but darken on drying; angular and granular; and strongly aromatic and pungent.



Geographical Distribution: *Aframomum* occurs throughout tropical Africa but it is cultivated mainly in West and Central Africa.[6]



Ethnomedicinal Uses: The genus is employed extensively in traditional medicine in West and Central Africa. In Ewe (Ghana), the common name for the plant, *megbe-dogboe*, means "never lacking for the sick." In Southern Nigeria, it is typically chewed with Kola nut as a masticatory agent. The fresh fruit is used as an aphrodisiac. The leaf is dispensed

for measles and applied externally for the treatment of leprosy. The root decoction is taken by nursing mothers to check excessive lactation and to control postpartum hemorrhage. The rhizome is used as an ingredient for the preparation of remedy for infertility to promote conception and the fruit is used as a tonic for sexual stimulation. The plant is also used as a purgative, galactagogue, anthelmintic, and homeostatic (hemostatic) agent. The seeds are used with the leaves of *Urera oblongifolia* as an external treatment for tumors. In Senegal, the seeds are mixed with salt and rubbed to the interior of the mouth as a treatment of sleeping sickness.

Constituents: The members of the genus yield essential oil in most parts of the plants. The seeds of *A. melegueta* have been shown to contain the benzenoids, gingerol, shagaol, and paradol.[7] The seeds of *A. danielli* obtained from Cameroon have been shown to contain labdane diterpenoids.[8] Other constituents of the genus include flavonoids,[9] monoterpenes,[10,11] and quinoids.[12] The chloroform extract of the seeds contains antioestrogenic diarylheptanoids, namely, gingerenone D, dihydrogingerenone A, dihydrogingerenone B, and dihydrogingerenone C.[13]

Pharmacological Studies: The essential oil obtained from the seeds and the benzenoids, paradol, gingerol, and shagaol have been shown to possess antimicrobial and antifungal activity.[14] The alcoholic extract was found lethal to snail hosts of schistosomes.[15] Extracts of the plant showed positive activity in cytotoxicity assay.[16] Studies on sexual behavior in rats have shown that *A. melegueta* modified the sexual behavior of male rats by increasing sexual arousal. The aqueous extract of the seeds of this plant was shown to significantly increase the penile erection index, as well as the frequencies of intromission and ejaculation. The plant extract was also found to enhance the orientation of males toward females by increasing mounting and anogenital investigatory behavior.[17] A review of *Aframomum* indicated its potential as a dietary supplement or spice for foods and as a potential source of new medicines for a variety of conditions, including inflammation, infections, and CNS disorders.[18] It has been suggested that the selective inhibition of COX-2 enzyme by *Aframomum* constituents may be indicative of more tolerable anti-inflammatory and analgesic compounds than most conventional NSAIDs.[19] The phenolic component has been shown to possess significant antiglycation and antioxidant effect,[20] which may be useful in its application as a dietary supplement.[21]

The potential benefit of grains of paradise in weight management has been demonstrated by the effect of extract of *Aframomum* and 6-paradol on the activation of thermogenesis in brown adipose tissue.[22] Intragastric injection of an extract or 6-paradol enhanced the efferent discharges of the sympathetic nerves in a dose-dependent manner. The enhanced nerve discharges were sustained for as long as 3 h. The rats did not become desensitized to the stimulatory effects of these compounds on sympathetic nerve activity. The tissue temperature of brown adipose tissue showed significant increase in rats injected with 6-paradol. These results demonstrate that *Aframomum* may be useful for the regulation of weight loss and weight maintenance.[23]

Toxicity: *Aframomum* is considered a safe herbal supplement and no human toxicity or allergic reaction has been reported. A 28-day subchronic toxicity study in male and female Sprague–Dawley rats to evaluate the safety of a grains of paradise extract showed a dose-related increase in absolute and relative liver weights in males and females dosed with 450 and 1500 mg/kg. There was a corresponding increase in alkaline phosphatase with no signs of steatosis or cirrhosis. At the same doses, there was a significant decrease in blood glucose in male rats.

Aloe vera

Overview

Aloe has long been used globally in food products, beverages, and cosmetics, and as an ingredient in several traditional medicine remedies. It yields a mucilaginous gel called aloe vera gel (AVG), which contains polysaccharides such as glucomannan and acemannan with several medicinal uses. AVG has been used for centuries to treat obesity and diabetes, and has immunomodulatory, anti-inflammatory, antiseptic, healing, and antitumor activities. Most of the activities are due to its pronounced antioxidant and anti-inflammatory activities. It has epigenetic modification properties and it is known to modulate the DNA methylation of some xenobiotics. *Aloe vera* elaborates a complex mixture of secondary metabolites, including phenolic compounds such as anthraquinones, anthranones, chromones, and pyrenes. The phenolics constituents of AVG are believed to be responsible for the use of the plant in the management of arteriosclerosis, diabetes, cancer, and neurodegenerative diseases. Several studies have reported the anticancer properties of AVG. These include studies on smoking and lung cancer, which showed that AVG can prevent pulmonary carcinogenesis and cancer of other tissues; inhibition of Ehrlich ascite carcinoma cells in acute myeloid leukemia and acute lymphocytes leukemia, with concentration-dependent cytotoxicity effect; activity against two cell lines of colon (DLD-1 and HT2); and study of aloe polysaccharides that exhibited anticancer effects by stimulating immune response through the activation of macrophages.

Pharmacognostical Profile

Botanical Name: *Aloe vera*
Synonyms: *A. barbadensis* Miller; *A. vulgaris* Lamk.; *A. indica* Royle.
Family: Asparagaceae
Common Names: Aloe vera, curacao aloe, aloe vera gel (AVG)



Description: A perennial herb with rosettes of long pointed leaves from shortly branched creeping rhizome. The leaves are brittle and exude a clear yellowish viscous sap when broken. They have soft marginal prickles. The flowers are yellow and borne in an elongated compact raceme from the center of the rosette. Propagation is by means of the rhizome branches since it does not produce fruit.

Habitat and Distribution: It grows in subtropical regions of the continent. The plant is probably native of South and East Africa and the Mediterranean regions, although it is widespread throughout the continent. It is not very discriminatory to soil types and climatic conditions but as a member of the Liliaceae family, it will prefer a well-drained clayey loam, with rainfall of at least 80 in. per annum.

Ethnomedicinal Uses: The fresh leaf is used for wound dressing and for the treatment of vertigo. In Nigeria, the exudate from freshly cut leaf is used in the treatment of guinea worm infestation. In Trinidad and Tobago, the exudate is mixed with egg white and used for cold and asthma, and to heal bruises, and is also used with seawater for stomach ulcers.[24] The dried exudates is used in the treatment of severe constipation. *Aloe vera* possesses healing, moisturizing, and emollient properties useful in a wide range of cosmetic formulations. It is employed as a humectant in skin preparations such as moisturizers, suntan lotions, and aftershave creams. It has been found to be useful for application to severely chapped skin.

Constituents: Aloes contain C-glycosides and resins. The crystalline glycoside known as "aloin" is used in pharmacy as a cathartic. It is, however, the gel that is said to contain several organic acids and the so-called "biostimulators," which the plant secretes as a repair agent upon physical injury, that have the topical healing properties. The plant also contains polysaccharides, glycoproteins, sterols, organic acids, and saponins.[1,25]

Preparation of *Aloe vera*: AVG is prepared in various ways depending on the manufacturing house. A common practice is to drain the free-flowing aloes first and then allow the leaves to be soaked in 15% ethanol solution in the dark for up to 14 days, and then the finely chopped material is subjected to a mill press. There is no scientific report on the differences (if any) between the pharmaceutical aloes and those processed for cosmetics use. The methods of preparation are highly customized and are subjects of several patents, with each manufacturing house claiming the superiority of its own method and product.

Pharmacological Studies: *Aloe vera* is one of the most effective wound- and burn-healing agents in current use. Several publications are available in the literature substantiating the healing properties of AVG, and only recent reports are reviewed here. Animal studies have shown that it possesses both oral and topical wound-healing activity.[26] In the oral experiment, animals were administered 25% *Aloe vera* in their drinking water for 2 months. The animals in the topical experiment were given 25% of the drug in a cream. The results showed that a 62.5% reduction in wound diameter was noted in mice that received 100 mg/kg/day oral dose of the substance and for the topically treated animals, a 50.8% reduction was recorded. In both groups, the wounds were induced on both sides of the vertebral column of ICR mice with a biopsy punch.

In another study, full-face dermabrasion was used to evaluate the wound-healing activity of AVG in comparison with the standard polyethylene oxide gel dressing.[27] It was found that by 24–48 h there was dramatic vasoconstriction and accompanying reduction in edema on the aloe vera-treated side; by the third to fourth day, there was less exudates and crusting at the site treated with the drug; the fifth to sixth day witnessed the complete reepithelialization of the aloe site. It was estimated that there was a 72-h acceleration of wound healing in the aloe vera-treated sites against the side of the face dressed with standard polyethylene oxide gel. It was observed that the acceleration of wound healing is significant in the reduction of bacterial contamination, possible keloid formation, and pigmentary changes. A suggestion has been made that the cicatrizant activity of *Aloe vera* is due, at least in part, to the gibberellin content of the plant.[28,613] Both aloe and gibberellins were shown to inhibit polymorphonuclear leukocyte infiltration into a site of gelatin-induced inflammation in diabetic animals.[29,614]

In the management of burn wounds, it was found that Hartley guinea pigs that received full-thickness burns covering 3% of their body surface area by direct contact with a hot plate were completely healed in 30 days against 50 days for the control group that were dressed with gauze occlusive dressing.[30] One comparative study of the burn wound-healing activity of *Aloe vera* and that of 1% silver sulfadiazine cream concluded that AVG hindered the healing process in second-degree burns in guinea pigs.[31] Aloe juice has been found to be effective in the treatment of third-degree x-ray burns and, more recently, it has been advocated in treating atomic radiation burns.[32,33]

At a dose of 60 mg/kg, *Aloe vera* powder was found to increase both the fertility rate and the litter size of female rabbits.[34] The plant was also very useful in menstrual irregularities and functional sterility.[35,36] *Aloe vera* is incorporated in several dietary supplements for its beneficial effects as an antioxidant and in the prevention of premature tissue aging. Interestingly, AVG does not include the sap of *Aloe vera*, which contains anthraquinones. AVG is widely used in cosmetics and toiletries for its moisturizing and revitalizing action. The organic whole leaf of *Aloe vera* is reported to aid in cellular repair and in digestion, assimilation of foods, vitamins, minerals, and other vital nutrients.[20] The rheological characteristics of native aloe gel and juice under dynamic and steady shear have been evaluated for their use in topical formulations. The damping of the elastic moduli and viscous moduli at various temperatures for aloe gel under oscillatory shear tests has been reported, which were observed due to the presence of weak, fibrous, and random structure of polysaccharides in it. The moduli for gel increased with increasing temperature and that for juice decreased with temperature. Prior to attaining the plateau region after certain shear rate, AVG and juice exhibited shear thinning behavior, with flow behavior index for aloe gel samples of 0.1 in the shear thinning region.[37]

Aloe vera has been found to be useful for the treatment of various diseases and studies have established that it possesses the following activities: antifungal,[38] management of diabetes, antihyperlipidemia, antiatherosclerosis, anti-inflammatory,[39] and management of gastrointestinal disorders.[40,615]

Toxicity: *Aloe vera* is generally regarded as safe and no serious adverse effects or toxicity has been reported. However, a caution was raised by the U.S. National Toxicology Program, which has found that rats grew tumors after drinking water spiked with an extract of the plant. The rodents were given relatively high doses of a whole leaf extract of *Aloe vera* over 2 years.[41] In rats that had drunk water containing 1.5% by weight of the extract, 39% of females and 74% of males had malignant or benign tumors in their large intestines. The report indicated that none of these growths were seen in rats given pure drinking water. It is believed that the tumors were probably caused by aloin A. In 2002, products containing aloin A or aloe extracts were removed from laxatives sold over the counter in U.S. pharmacies because manufacturers did not provide sufficient safety information to the U.S. Food and Drug Administration (FDA).[42]

Cape Aloe

Overview

Over 80 species of *Aloe* (family Liliaceae) occur in various parts of the world. The main species found growing in Africa is *Aloe ferox*, which yields the so-called Cape aloe. Another common species is *Aloe vera* (discussed above), which is the source of curacao aloe. Socotrine and Zanzibar varieties originate from *Aloe perryi*. Cape aloe is used mainly

as a general tonic and as a laxative. It contains anthraquinone glycosides, the principal one being a yellow, crystalline substance called barboloin and aloin. Aloin is a bitter-tasting yellow crystal, and it is a C-glycoside derivative of an anthraquinone. Although the C-glycoside side chain of aloin is not easily hydrolyzed *in vitro*, orally administered aloin is known to be hydrolyzed by esterases secreted by intestinal microflora. Once the C-glycoside is hydrolyzed, it forms aloe emodin anthrone, which is further auto-oxidized to the quinone aloe emodin. Both *Aloe* species have been used for the treatment of different types of cancer.

Pharmacognostical Profile

Botanical Name: *Aloe ferox* Miller

Synonyms: *Pachidendron ferox* (Mill.) Haw.; *Pachidendron supralaeva* (Haw.) Haw.; *Pachidendron pseudo ferox* (Salm-Dyck) Haw.; *Aloe galpini* Baker.; *Aloe horrida* Haw.; *Aloe muricata* Haw.

Family: Asparagaceae

Common Names: Aloe, Cape aloe

African Names: Arabic; Swahili: shubiri

Description: The genus *Aloe* includes herbs, shrubs, and trees, bearing spikes of white, yellow, or red flowers. The leaves are fleshy, strongly cuticularized, and are prickly at the margins. *A. ferox* is a shrub, 3–4 m in height, and about 12 cm in diameter, with a large rosette of leaves. The leaves are oval-lanceolate, 40–60 cm long and 10–12 cm wide, with thorny ridge and edges. Flowers have perianth of 2.5 cm in diameter, tinged with yellow and purplish-blue, striped with red and green.

Habitat and Distribution: It is a subtropical plant but widely cultivated in dry forest areas of the continent.

Constituents: *Aloe* contains anthraquinone glycosides, principally a yellow, crystalline substance called barboloin as well as resin and aloe emodin. The pharmaceutical "aloe" is the solid residue obtained by evaporating the liquid that drains from the parenchyma tissue in the center of the leaves of various species of *Aloe.* The aloe mostly used in cosmetics formulations is the curacao aloe from *A. barbadensis* Miller (*Aloe vera* Linne, see above). The major aglycone found in *A. ferox* is aloe emodin and is associated with the decomposition product aloe-emodin-9-anthrone.

Production of Aloes: Aloes for pharmaceutical uses are prepared from the wild species of *A. ferox* or cultivated species of *A. barbadensis* by making transverse cuts near the base of the leaves and collecting the ensuing juice for about 6 h. It is concentrated by boiling about 4 h on an open flame. *Aloe ferox* gel can be differentiated from AVG by the analysis of their monosaccharide content; *A. ferox* yields a mixture of glucose and galactose, whereas *A. vera* contains mainly mannose.[43]

Pharmacological Studies: The main pharmaceutical use of the aloes is as a laxative, the activity being due to anthraquinone glycosides. An anaerobic bacterium *Eubacterium* sp. has been isolated from human feces. It is capable of transforming barboloin to aloin emodin anthrone, and the bacterium is believed to be one of the bacteria responsible for metabolizing barboloin in the intestine.[44] The mechanism of cathartic action of aloe-emodin-9-anthrone causes a significant increase in water content of the rat large intestine, which has been attributed to its inhibition of rat colonic Na+, K(+)-adenosine triphosphatase (ATPase) *in vitro*, and increase in the pericellular permeability across the rat colonic mucosa *in vivo*.[45] Aloes have also been found to be effective as antihyperglycemics and hypoglycemics in experimental animals.[46] Aloe has been identified as one of the most commonly used herbal proprietary products.[47]

In a comparative analysis of the gels from various *Aloe* species for wound-healing and antifungal properties, *A. ferox* was found to have the highest antifungal activity, measured as absence of or low percentage of infected wounds.[48] The antifungal activity was positively correlated with gel aloin content. The use of Cape aloe in traditional medicine in Africa as a general tonic and restorative medicine seems to be validated by the scientific evidence on its anti-inflammatory, anticholinesterase, and antioxidant activities,[49] as well as its antimicrobial and wound-healing properties.[50]

Aridan

Overview

Aridan, *Tetrapleura tetraptera*, is a West African spice used in the preparation of the popular fish soup "Banga soup." It produces a very aromatic volatile oil with a pleasant taste. It also contains saponins, oleanolic acid glycosides, scopoletin, and coumarin, as well as tannins, flavonoids, and starch. Alcoholic extracts of the fruit showed sedative effect in mice within 30–40 min after intraperitoneal injection of leptazol, giving a protection score of 60% against the convulsant effects of the latter. One of the major constituents, scopoletin, has been shown to possess *in vitro* and *in vivo* antibronchoconstrictor and antiarrhythmic effects. Extracts of the fruits and the powdered drug exhibited molluscicidal activity. It has clinical antimalarial activity that is comparable to that of the standard antimalarial drug, chloroquine. It is also used as an anti-inflammatory, antihypercholesterolemic, and antidiabetic phytomedicine in oral formulations in tablets and teas.

Pharmacognostical Profile

Botanical Name: *Tetrapleura tetraptera* (Schum. & Thonn.) Taub.

Synonyms: *Adenanthera tetraptera* Schum. & Thonn.; *T. thonningii* Benth.

Family: Leguminosae

Common Names: Aridan, aidan

African Names: Bini: ighimiakia; Efik: edeminang; Etsako: imininie; Twi: prekese (*Prɛkɛsɛ*); Igbo: ohikogho

Description: *Tetrapleura tetraptera* is a medium-size tree, up to 24 m high and 1.5 m in girth. It has sharp buttresses, fern-like foliage, and silvery gray to reddish smooth bark. The leaves are very sensitive, bipinnate, 6–8 pairs of pinnae. The leaflets are opposite, alternate, oblong-elliptic, with rounded ends, practically glabrous, 8–12 pairs. It has prominently grooved, wing-like ribs, slightly curved, dark purple-brown, glabrous, and glassy. Two of the wings contain soft sugary pulp, oily and aromatic, and the other two are woody.[1]

Habitat and Distribution: It occurs in deciduous and evergreen forests. It is found in Senegal, Sierra Leone, Ghana, Nigeria, Cameroon, Kenya, Zimbabwe, and Tanzania.

Culinary (Food) Use: The aridan plant is used in West Africa to flavor soups taken as general tonics and stimulants or as part of postpartum diet therapy.

Ethnomedicinal Uses: The powdered fruit is used as fish poison and in ointment for the treatment of skin diseases. An infusion of the fruits is used in Ghana as a bath solution for fevers and malaria. The stem bark extracts have been used among other things for gonorrhea, viral diseases, and as a tonic. A decoction of the roots used as a bath solution for fevers and malaria is also useful in the treatment of jaundice. The fruits are also added as

ingredient to anticonvulsant remedies. It is an ingredient in traditional remedies for arthritis and other inflammatory conditions, asthma, diabetes mellitus, hypertension, and epilepsy.

Constituents: The root bark has been shown to contain saponins and tannins. Oleanolic acid glycosides, scopoletin, and coumarin have been isolated from the fruit.[51,52]

Pharmacological Studies: Alcoholic extracts of the fruit showed a sedative effect in mice within 30–40 min after intraperitoneal injection of leptazol, giving a protection score of 60% against the convulsant effects of the latter. Scopoletin has been shown to possess *in vitro* and *in vivo* antibronchoconstrictor and antiarrhythmic effects.[1] Extracts of the fruits and the powdered drug exhibited molluscicidal activity.[53] Its antimalarial activity has been evaluated and at a dose of 300–900 mg/kg day exhibited significant ($P < 0.05$) blood schizonticidal activity both in a 4-day early infection test and in established infection with a considerable mean survival time comparable to that of the standard drug, chloroquine, 5 mg/kg day.[54]

Laboratory studies showed that the aqueous extract of *T. tetraptera* fruit possesses anti-inflammatory and hypoglycemic properties. *T. tetraptera* extract (50–800 mg/kg p.o.) produced dose-related, significant reductions ($P < 0.05$–0.001) of the fresh egg albumin-induced acute inflammation of the rat hind paw edema. In the antidiabetic assay, the plant extract (50–800 mg/kg p.o.) also produced dose-dependent, significant reductions ($P < 0.05$–0.001) in the blood glucose concentrations of both fasted normal and fasted diabetic rats.[55] A commercial product that contains dried aqueous extract of *T. tetraptera* is marketed in Nigeria by Intercedd Health Products as antioxidant and for the treatment of hypercholesterol.

Balanites: Desert Date

Overview

Desert date grows in the Sahel region of Africa. It is valuable for the hypoglycemic and hypocholesterolemic properties of the fruit pulp. The plant also contains disgenin and yamogenin, which are starting points for the manufacture of cortisone and other corticosteroid drugs, especially sex hormones and oral contraceptives. Desert date fruits have interesting biological activities, including antioxidant, antimutagenic, anti-inflammatory, anticancer, antimicrobial, and immunostimulant properties. The fruits have been shown to possess significant antidiabetic activity and inhibition of the aldose reductase enzyme, a key mediator for the onset of diabetic complications. The antidiabetic effect of balanites fruit may be due to the presence of steroidal saponins containing diosgenin as an aglycon (Balanitin A–F) and the alkaloid trigonelline.

Pharmacognostical Profile

Botanical Name: *Balanites aegyptiaca* (L) Del.

Synonyms: *Ximenia aegyptiaca* L.; *Agialida senegalenses* v. Tiegh.; *A. barteri* v. Tiegh.; *Balanites zizyphoides* Mldbr. & Schltr.

The genus *Balanites* has hitherto been placed in the plant family Zygophyllaceae or Simaroubaceae.

Related Species: *Balanites wilsoniana* Dawe and Sprague

Family: Zygophyllaceae

Common Names: Desert date, soap berry, thorn tree

African Name: Arabic: bhanitez; Hausa: aduwa; Fulani: tanni; Kanauri: kingo; Swahili: mnyara, njienja; Yoruba: adowa. For *B. wilsoniana*: Igbo: ngwu-awusa; Bini: ubogho; Yoruba: budare

Description: A savanna tree that grows up to 10 m, desert date is easily recognized by the long straight green spines arranged spirally along the branches, each spine with a two-leaflet compound leaf below it. It has a remarkably fluted trunk and a spherical crown; the bark is grayish-brown and has ragged fissures and yellowish-green patches that are exposed by scaling of the bark.[56] It has distinctive leaves with two leaflets up to 5 cm long on leaf stalks about 2 cm long; broad, slightly obovate, blunt, or rounded at the apex, cunneate; young leaves have short hairs. The yellowish-green flowers are borne above the leaf axils in short clusters; the (five) greenish petals ca. 5 cm long, individual flower stalks (five) up to 1 cm long: yellow (10) stamens, and an ovary of five fused shiny dark-green carpels—March–June. Fruits are produced between March and October. The fruit has a single hard pointed seed, about 2.5 cm long and 1.2 cm in diameter; broadly oblong ellipsoid, green and shortly velvety when young, turning yellowish and glabrous when ripe and resembling a small date; it has a thin hard skin and a pale brown sticky edible fleshy pulp.

The related species *B. wilsoniana* is a lowland large forest tree found in the southern parts of West Africa and in parts of East Africa. It is distinguishable from *B. aegyptiaca*, which grows in the north, by its large leaves and by the lack of spines on the flowering branches. The leaflets have distinct stalks and the petals are hairy inside. The uses, constituents, and other notes on *B. aegpyptiaca* should also apply to *B. wilsoniana.*

Habitat and Distribution: Sahel-Savannah regions and drier parts of middle belt zones of Nigeria, Ghana, and Côte D'Ivoire, and cultivated as a fruit tree in semi-Savannah parts of the continent.

Culinary (Food) Uses: In the Sahel region of West Africa, the fleshy pulp of both the unripe and ripe fruit is consumed as snacks and eaten dried or fresh. The fruit pulp is used in the preparation of a drink and sometimes fermented into an alcoholic beverage. In Ghana, it is used to prepare sweetmeats. It is used as a soup-flavoring ingredient and sometimes fermented in the preparation of the West African "dawadawa." The young leaves and tender shoots are used as vegetable for the preparation of soups and stews. The flowers are also sucked for their nectar.[57]

Ethnomedicinal Uses: The plant features prominently in Hausa ethnomedicine and has been found most useful for other household purposes. A Bornu proverb extols *Balanites* thus: "A bito tree and a milk cow are just the same." The fruit pulp is a mild purgative, but when ripe can be used in making pleasant drinks or fermented into alcoholic beverages. The fruit and bark are lethal to small freshwater snails (mollusks), which act as intermediary hosts to bilharzia, and have been recommended for the control of schistosomiasis. The bark decoction is used as an abortifacient. The oil of the fruit kernel is employed for the dressing of wounds and as an embrocation in rheumatism.[58] The roots and fruits are used as anthelmintics, and as arrow poison antidote; the fruit alone is employed for the treatment of liver and spleen disorders; the root has been indicated for the treatment of malaria, herpes zoster, and venereal diseases.[59]

Other Uses: The gelatinous substance on top of the fruits is used in making sweet meats. Saponin occurs in the roots, bark, wood chips, and fruits; hence they are used in washing clothes. The gum from the trunk when fresh is pleasant to suck. The leaves are occasionally used as a vegetable and are eaten by goats, camels, and cattle. The root is processed with charcoal and oil to produce local ink, and the hard seeds are used for rosary beads and necklaces, and also in the game of darra. The fine-grained wood is used for implements and furniture, and various plant parts are used for religious rituals.

Constituents: The dried seeds yield about 48% of a fixed oil, *Zachunoil*, and the seed cake contains 50% protein.[60] The seeds, leaves, fruits pulp, bark, and root contain saponin, including the tetraglycoside of diosgenin.[61] The diosgenin content of the whole dried plant has been evaluated as 5.6%; the predominant genin (two-thirds) in the plant is, however, the C-25 epimer of diosgenin, yamogenin.[62] The plant holds promise as a source of steroidal sapogenins for the hemisynthesis of corticosteroids and hormones.[63] Two furanocoumarins, bergapten and (+)- marmesin, have been isolated from *Balanites*.[64] Trigonelline (3-carboxy-1-methyl pyridinium) has been identified as a relevant bioactivity and taste imparting component in *Balanites aegyptiaca* fruit, using ^{1}H NMR of crude extracts without any fractionation or isolation step.[65] UPLC–MS of the crude extract additionally revealed the presence of flavonoids in the fruits, with a flavonoid pattern showing quercetin/isorhamnetin flavonol conjugates and epicatechin also occurring but at much lower levels.

Pharmacological Studies: The molluscicidal activity of the plant has been investigated, and because of its lethality to both freshwater snails (which act as an intermediate host for bilharzia) and the minute free stages of the schistosomes, the plant has been recommended for planting along the banks of infested rivers.[66] Malcom and Sofowora reported on the antimicrobial properties of the plant.[67] The anticancer properties of the plant have also been investigated.[68] *Balanites* extract has been reported to possess significant antidiabetic activity. It reduced blood glucose level by 24% and significantly decreased liver glucose-6-phosphatase activity in diabetic rats. The extract also showed *in vitro* inhibition of α-amylase activity in a dose-dependent manner. This inhibition was reversed by increasing substrate concentration in a pattern, which complies well with the effect of competitive inhibitors. Furthermore, this *in vitro* inhibition was confirmed by *in vivo* suppression of starch digestion and absorption induced by the plant extract in normal rats. These findings suggest that the hypoglycemic effect of *Balanites* is mediated through insulinomimetic effect as well as the inhibition of intestinal α-amylase activity.[69] The butanol fraction of the 70% ethanol extract was shown to possess inhibitory activity against the aldose reductase enzyme ($IC_{50} = 55.0 \pm 6$ μg/mL). A subfraction D exhibited the highest inhibitory activity ($IC_{50} = 12.8 \pm 1$ μg/mL) and the activity was attributed to the isolated furostanol saponins.[70]

The antidiabetic effect of balanites fruit may be due to the presence of steroidal saponins containing diosgenin as an aglycon (Balanitin A–F) and the alkaloid trigonelline.

Bambara Groundnut

Overview

Bambara groundnut represents the third most important grain legume (after groundnuts, *Arachis hypogea*, and cowpeas, *Vigna unguiculata*) in Africa. It is not considered a staple food or a lucrative cash crop but a snack or food supplement that is cultivated by women and poor farmers. Bambara groundnut, however, is considered to possess an exceptional nutrient balance and is cited as a rare example of a complete food. It contains sufficient quantities of carbohydrate (65%), protein (18%), and lipids (6.5%) to sustain human life. It is resistant to high temperature and is suitable for marginal soils where other leguminous crops cannot be grown. In addition, it makes very little demand on the soil and has a high nutritive value with a good amino acid profile, containing high lysine and methionine. For these reasons, it is not prone to the risk of total harvest failure even in semiarid regions

with low and uncertain rainfall. Owing to its high protein content, it is a very important crop for poorer people in Africa who cannot afford expensive animal protein. It has been formulated as a weaning food for children. The Intercedd in Nigeria has formulated a series of supplements based on bambara groundnut and cocoa powder for nutritionally at-risk populations such as severely malnourished children, diabetics, and the elderly.

Pharmacognostical Profile

Botanical Name: *Vigna subterranea* (L.) Verdc.

Synonyms: *Arachis africana* Burm. f.; *Glycine subterranea* L.; *Voandzeia subterranea* (L.) Thouars; *Voandzeia subterranea* (L.) DC.

Family: Fabaceae

Common Names: Bambara bean, Congo goober, earth pea, ground bean, hog peanut, or jugo beans

African Names: Bambara (Bamanankan, Mali): tiganingelen or tiganinkurun; Ga (Ghana): Akwei; Ewe (Ghana): azi nogui; Igbo: okpa, okpa otuanya; Hausa: gurjiya, kwaruru, juijiya; Yoruba: epi roui; Goemai: kwam; Kanuri: ngangala; Shona: nyimo; Ndebele: ndlubu; Silozi: lituu; Oshiwambo: ofukwa; Swahili: njugumawe, njugu; ciBemba (Zambia): ntoyo; kiKaonde (Zambia): katoyo; chiTonga: bwiila; Shangaan: tindluwa; siSwati (Swaziland): tindlubu; Malagasy: voanjobory

Description: Bambara groundnut is a prostrate, herbaceous annual legume, with a well-developed compact tap root system bearing abundant geotropic lateral roots.[71] The root system consists of a tap root with lateral roots lower down, with rounded and sometimes lobed nodules. The leaves are alternate, trifoliolate, glabrous; stipules c. 3 mm long, spurred, striate; the petiole erect, grooved, up to 30 cm long, thickened at base, rachis (0.1–)1–2.5 cm long; the stipels ovate-oblong, up to 3 mm long; petiolules 1–3 mm long; the leaflets elliptical to oblanceolate, 3–10 cm × 1–5 cm. Usually, two papilionaceous flowers are attached to the peduncle.



The flowers are yellow, and flowering is indeterminate. During pollination and fertilization, the peduncle elongates to bring the ovaries to ground level. After fertilization, the pedicles penetrate the soil to form pods with either one or two seeds. The pods occur on or

just below the soil surface. Bambara groundnut landraces differ in many aspects from each other, with a wide variety of seed and pod colors, and growth habits varying from bunch type, to semibunch and spreading.[72]



Habitat and Distribution: Bambara groundnut originated from north-eastern Nigeria and northern Cameroon. Its use as a pulse in West Africa was recorded by Arabic travelers in the fourteenth century. It is a common crop in most of the Sahel region but it occurs in the wild from Central Nigeria to southern Sudan. It is now pantropic, being cultivated throughout tropical Africa, and to a lesser extent in tropical parts of the Americas, Asia, and Australia.

Culinary (Food) Use: The seeds are boiled with and eaten as beans. Seeds can also be ground, and the subsequent flour used to make cakes. In the Nsukka-Enugu areas of Nigeria, a popular bean cake is prepared from the ground seeds and used as a base for the addition of many nutrients. The dried seeds, either whole or split, are boiled with maize or plantains to prepare a porridge. They are sometimes soaked in water and ground into a paste, which is used to prepare fried or steamed dishes. Immature seeds are often boiled with salt and eaten as a snack. The seeds can also be used to prepare vegetable milk and fermented products similar to tempeh (from *Glycine max* L.) and dawadawa (*Parkia biglobosa*).



Ethnomedicinal Uses: The Igbo (Nigeria) use the plant to treat venereal diseases. The leaf preparations are applied to abscesses and infected wounds, leaf sap is applied to the eyes to treat epilepsy, and the roots are sometimes taken as an aphrodisiac. Pounded seeds mixed with water are administered to treat cataracts.

Constituents: Bambara nuts are considered to possess an exceptional nutrient balance, and cited as a rare example of a complete food. They contain sufficient quantities of carbohydrate (65%), protein (18%), and lipids (6.5%) to sustain human life. A report of the protein content using MudPit (multidimensional protein identification technology) and LC-MALDI TOF-TOF (liquid chromatography-matrix-assisted laser desorption ionization tandem time-of-flight) mass spectrometry identified a total of 10 and 12 different types of proteins present in other legume species in the malted and dry seeds, respectively, from the 214 peptides isolated after searching 586 proteins of the genus *Vigna*. Seed storage protein B and vicilin were observed to be the major proteins common to both malted and dry seeds and are similar to *Vigna luteola*. Some of the other proteins observed showed amino acid sequence homology with *Vigna radiata* and *Vigna unguiculata* species. The following proteins: BV1, heat shock protein, and Bowman–Birk inhibitor (a protease), were observed only in the malted state.[73] The protein contains high lysine and methionine content, with the total essential amino acids amounting to an average of 32.7% and lysine was found to be the most predominant essential amino acid with an average value of 10.3%. It is also rich in iron and other minerals. An analysis of bambara groundnut yielded 3.7% crude lipids in the ethanol-soluble fraction of the dry material. Linoleic, palmitic, and linolenic acids were the most predominant fatty acids with average values of 44%, 30%, and 21%, respectively. Stearic acid was present in small quantities. Sugar analysis showed that 30% of the neutral sugars were present and identified essentially as glucose and galactose.[74] The seeds also contain flavonoids and anthocyanins.[75]

Pharmacological Studies: Most of the work done on bambara nuts has been on the nutritional value rather than on pharmacological activities. The beans are recognized throughout West Africa as a therapy for the treatment of anemia. During the Nigeria–Biafra civil war, bambara beans were helpful to minimize the incidence of *kwashiorkor*, the common protein deficiency disease in young children. As was reported in the *Lost Crops of Africa* (Vol. 2),[76] a trial has been conducted of "milks" prepared from bambara bean, cowpea, pigeon pea, and soybean. Whereas all were declared acceptable, the scientists ranked bambara milk first in flavor, nutritional value, and color. The mothers and (seemingly) their babies preferred bambara milk above the others. The seed contains a remarkably high concentration of soluble fiber, a nonnutrient believed to reduce the incidence of heart disease and to help prevent colon cancer. The immature fresh seeds are chewed to stop nausea and vomiting, and in the management of morning sickness in pregnancy. Bambara groundnut seeds have also been used to treat some malignancies and inflammatory disorders in Africa.[77] Reports suggest that the bambara groundnut seeds with condensed tannins in low concentrations have beneficial effects in human nutrition and health.

Agriculture and Commerce: Bambara nuts are cultivated by small-scale farmers, and a limited number of people in rural areas grow it as a subsistence crop. Farmers sow seeds of various landraces in different agroecological environments. Cultivation is almost exclusively using traditional methods and traditional landraces. Much of the harvest is consumed by the farm family, for whom it is a major source of protein and a lifesaver during the lean season, the period before the new crops are ready to harvest and the old have been eaten. Bambara is increasingly becoming a cash crop, the dried fresh beans sell for a premium. In the south-eastern states of Nigeria, a bean cake called okpa provides a regular

source of cash income to both rural farmers and local food vendors. It is a largely neglected crop but the overall annual production is around 400,000 tons, and it fetches a comparable price in the local markets.

"How to Eat It"—Taken from FAO[78]

Dumplings

Ingredients: 500 g bambara nut flour, 50 mL palm oil, 2 stock cubes (crushed), 1 small onion (chopped fine), ground chilli pepper (to taste), salt (to taste), and warm water (as needed). Container: bowls, aluminum foil bags, or plantain leaves.

Preparation: Pour the flour into a bowl, add the palm oil and mix thoroughly, until the flour changes from white to orange or yellow. Add the warm water and mix thoroughly, making sure the mixture is not too watery and is without lumps. Add the stock cubes, onions, chilli pepper, and salt to taste. Mix thoroughly. Pour the mixture into a container and place in a pot of boiling water. Boil for 45–60 min, adding water if too dry. Leave to cool and then serve.

Baobab

Overview

Baobab, mother of the Sahel, provides edible leaves, fruits, and seeds. It is greatly valued throughout the drier parts of West and Northern Africa for its ability to support human survival by its ability to provide food, water, and shelter in the open grassland of the Sahel. The name baobab is also used to describe eight other related species found in Madagascar, Africa, and the Middle East. The leaves are rich in protein and contain the essential amino acids, including lysine. The fruits and seeds contain flavonoids, fatty acids, vitamins, and minerals and possess antioxidant activity. Phytosterols such as campesterol, stigmasterol, isoflucasterol, and avenasterol have been isolated from the seeds. The fruit juice has been incorporated in commercial drinks as a health-promoting product.

Pharmacognostical Profile

Botanical Name: *Adansonia digitata* Linn.

Synonyms: *Adansonia bahobab* Gaertn.; *Adansonia integrifolia* Raf.; *Adansonia scutula* Steud.; *Adansonia situla* (Lour.) Spreng.; *Adansonia somalensis* Chiov.; *Adansonia sphaerocarpa* A.Chev.; *Adansonia sulcata* A.Chev.; *Baobabus digitata* (L.) Kuntze; *Ophelus sitularius* Lour

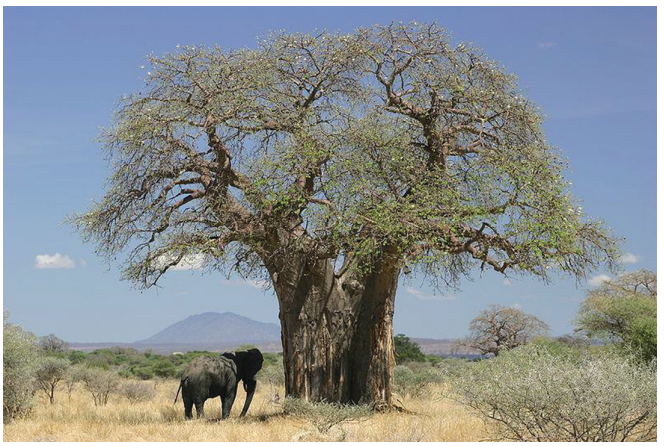
Related Species: *Adansonia fony* Baill., *Adansonia grandidieri* Baill., *Adansonia gregorii* F.Muell., *Adansonia madagascariensis* Baill., *Adansonia perrieri* Capuron, *Adansonia suarezensis* H.Perrier, *Adansonia za* Baill.

Family: Malvaceae

Common Name: Baobab, monkey-bread tree, dead-rat tree, cream-of-tartar tree, magic tree, chemist tree, symbol of the earth, upside-down

African Names: Ashanti: odade; Hausa: kuka, bumbu, murna; Bambara: sira; Bisa: horgo, poh-go; Gourounsi-Lele: koukoulou, ekoulou; Peul: boki, olohi; Igbo: oyili-akpu; Wolof: gui, bui, gif; Yoruba: ose, oske; Baoule: frondo; Malinke: sira; Senoufo: ngigue; Swahili: mbuyu, mkuu hapingwa, mkuu hafungwa, muuyu

Description: This is a huge and dominant species in the Savannah and Sahel regions of Africa. Its massive structure and its bottle shape make it easy to identify. The tree is rather remarkable for its enormous trunk in comparison with the small crown of foliage. The trunk is comparatively short, 13–17 m high but 10–14 m or more in girth, with short thick branches. A specimen with a girth of 37 m has been recorded. The bark is unarmed. The leaves are palmate with five sessile leaflets. The flowers are large, 12.5–15 cm in diameter, white, with numerous monadelphous purple stamens. The flowers are oblong, 15–20 cm long, pendulous on long stalks, woody, indehiscent, with large seeds embedded in dry acid pulp.



Habitat and Distribution: Baobab occurs naturally almost throughout the drier parts of the continent and is available all year round. Outside Africa, it has been widely introduced in tropical and subtropical regions as a commercial crop. Although it was introduced late in many Central African countries, it is now a valued crop in many countries in that region. It is still not common in Rwanda, Burundi, Djibouti, and Uganda. It has been introduced in Madagascar and many other Indian Ocean islands. In West Africa, it often occurs in northern parts of the subregion from Nigeria to Senegal in Savannah forests and in baobab orchards around villages.

Culinary (Food) Uses: The baobab's leaves, fruits, and seeds are all edible. The fruit pulp is used to make fruit juices. The seeds are a source of flour used to prepare meal for diabetics. The leaves are used as vegetables for soups and sauces, and in yam and millet porridges. In most parts of Africa, the leaves of the baobab are used either fresh as a cooked vegetable or dried and powdered as an ingredient of soups and sauces. The shoots and roots of seedlings are eaten as well. The roots are boiled and eaten in West Africa in times of famine. The flowers are eaten raw. The fruit contains soft, white, edible, and nutritious flesh ("monkey bread"). In northern Nigeria, it is used to curdle milk, eaten as a sweet, and used in making gruel and refreshing drinks and ice cream. In Sudan, it is made into a milk-like drink called "gubdi." The powdered fruit flesh is added to cold liquid, thus preserving vitamins. An emulsion of the fruit pulp may be used to adulterate milk. The dried pulp is used as a substitute for cream of tartar in baking.[4]

Ethnomedicinal Uses: This majestic tree is revered in Africa for its medicinal and nutritional value. Many parts of the plant are used to treat various ailments such as diarrhea, malaria, and microbial infections. Other activities include treatment of urinary tract disorders, mild asthma, fatigue, dysentery, kidney and bladder diseases and a diaphoretic for fevers, anti-inflammatory, expectorant, astringent, and tonic. It is reported that it is an excellent antioxidant due to the vitamin C content. It has a widely held reputation as an antiviral and anti-inflammatory medicine. The leaves are most valuable for medicinal uses but the fruits and stem bark are also used in the preparation of remedies.

Constituents: The baobab is rich in vitamins, amino acids, fiber, and several nutritive substances.[79] The fruit pulp has 10 times the vitamin C content than of an orange w/w. It also contains per 100 g: water 8.7 g, energy 1290 kJ (308 kcal), protein 2.7 g, fat 0.2 g, carbohydrate 73.7 g, fiber 8.9 g, Ca 335 mg, Mg 167 mg, P 76.2 mg, Fe 2.7 mg, Zn 1.0 mg, thiamine 0.62 mg, riboflavin 0.14 mg, niacin 2.7 mg, ascorbic acid 209 mg. The seed, which is about 55% seed coat and 45% kernel, contains per 100 g of kernel: water 8.1 g, energy 1805 kJ (431 kcal), protein 33.7 g, fat 30.6 g, carbohydrate 4.8 g, fiber 16.9 g, Ca 273 mg, Mg 640 mg, P 5.1 mg, Fe 6.6 mg, Zn 6.7 mg, thiamine 0.25 mg, riboflavin 0.14 mg, and niacin 1.0 mg. The fatty acid composition is linoleic acid 34.9%, oleic acid 32.3%, palmitic acid 26.5%, and stearic acid 4.4%. An alkaloid, adansonin, has been identified from the bark of the baobab tree and it is believed to be the active agent responsible for the antimalarial properties of baobab tree bark. The seed protein contains a large amount of lysine, but its use as a protein source is limited by the presence of antinutritional factors such as trypsin, tannins, oxalic acid, protease inhibitors, phytate, and amylase inhibitors. Such constituents can be reduced by improved processing methods[80]; however, they may confer added functional benefits to the plant products. An ultrahigh-performance liquid chromatography with high-resolution mass spectrometry method has been used to analyze the chemical compositions of the hydro-alcoholic extract of the dried fruit pulp and hydroxycinnamic acid glycosides, iridoid glycosides, and phenylpropanoid glycosides were found as major components in baobab.[81] Their structures were determined by means of spectroscopic analyses, including HRMS, ^{1}H and ^{13}C NMR, and 2D experiments (COSY, HSQC, and HMBC).

Pharmacology: Baobab is well known for its antioxidant, anti-inflammatory, and general nutritive properties. The plethora of biological activities attributed to baobab is traceable to the constituents found in the plant. The analgesic effect of the hot aqueous fruit of *A. digitata in vivo* (mice) has been established. It was noted that the extract exhibited analgesic activity 2 h after administration. At 800 mg/kg, the reaction time was 15.4 min in comparison to the negative control (10.2 min). The petroleum ether extract containing seed oil of baobab also showed analgesic activity. The extract exhibited analgesic activity with the tail flick response in 6.1 s, which was not statistically different from aspirin used as positive control. The antipyretic activity of baobab extract has been established by laboratory studies in rats.

The hot water extract of the fruits showed *in vivo* anti-inflammatory activity in the rat paw formalin-induced edema test. The extract tested at a dose of 400 and 800 mg/kg inhibited formalin-induced edema. After 24 h administration of the aqueous extract, the mean swelling of the foot was 1.81 and 1.75 mm for 400 and 800 mg/kg, respectively, in comparison to the negative control (6.35 mm).[82] The DMSO of fruit pulp extract and aqueous leaf extract showed significant inhibition against cytokine IL-8.[83]

The capacity of baobab extracts to reduce the mobility of *Trypanosoma brucei*, which causes sleeping sickness, was evaluated using four different extracts (petroleum ether,

chloroform, water, and methanol) obtained from the leaves and the bark. The time at which mobility stops ranged between 10 and 45 min for the root bark, while with the leaves, the mobility ceased between 25 and 45 min, when various extracts were tested at 2 mg/mL.[84] The extracts also possess only modest activity against the malaria causing parasite, *Plasmodium falciparum.*

Because of the widespread use of baobab extract in the treatment of viral infections in West African traditional medicine, several *in vitro* and *in vivo* studies have been carried out to determine the antiviral activity of various baobab plant parts.[85] In a comparative study by Ananil et al.,[86] baobab extract was found more active than several herbal extracts tested against the herpes simplex, sindbis, and polio viruses. A later investigation was conducted by Vimalanathan and Hudson[83] on the antiviral activity of leaves, fruit pulp, and seed extracted with water, DMSO, and methanol. The study was conducted using the minimum inhibitory concentration method against the influenza virus, herpes simplex virus, and respiratory syncytial virus. It was shown that the influenza virus was very susceptible, while the respiratory syncytial virus was resistant. The leaf extract exhibited the most promising activity against the influenza virus with the MIC value ranging from 0.12 µg/mL (DMSO) to 2.8 µg/mL (water). The activity of the leaf extract was promising against the herpes simplex virus (MIC value: 1.0–11.7 µg/mL), while the pulp and the seed exhibited much lower activity (MIC value: 72.5 µg/mL). The study clearly demonstrated variation in biological activity when different plant parts are investigated. Furthermore, the anti-HSV activity was considerably enhanced by light, especially long-wavelength UV although they all showed "dark" antiviral activity as well. Thus, all the extracts contained antiviral photosensitizers. Baobab extracts have also shown in laboratory studies to possess insecticidal and insect repellant, antioxidant, drug permeation enhancement, hepatoprotective, hypoglycemic, and hypolipidemic activities.[87]

Formulation and Dosage Forms: All parts of the plant are used either for food or medicine. Several proprietary products are available with baobab as a major ingredient. The seeds are eaten raw or roasted and are used to thicken and flavor soup. Fermentation of the seed kernels improves the nutritional value. In coastal Kenya and Tanzania, the pulp-coated seeds are colored and sugar-coated and sold as sweets. The seeds are used to adulterate groundnuts and sometimes used as a coffee substitute. The oil extracted from the seed kernels by boiling and distillation is semifluid, golden yellow, gently scented, and nondrying, and has a long shelf life. It is used for cooking and in the cosmetics industry. The most prominent commercial product is the sun-dried fruit pulp. Roasting and fermentation of both the fruit pulp and seeds improve their chemical composition and it is believed that the fermented product with decreased tannin content provides a better ingredient in traditional medicine.

Spray drying of the fruit pulp significantly elevated fat, total sugars, K and P contents, as well as bulk density and pH, while moisture, protein, fiber, ash, ascorbic acid, and Na, Ca, and Fe contents were reduced significantly. However, color and reducing and nonreducing sugars were not affected by spray drying. The solubility of the spray-dried powder was significantly reduced as a result of treatment with gum Arabic, sugar, and carboxy methyl cellulose (CMC). The spray-dried powder obtained from the pure extract of the pulp showed significantly better reconstitution properties (wettability, dispersibility, and solubility) in comparison to those prepared by addition of CMC or gum Arabic. The overall quality of the reconstituted drink prepared from the sprayed powder produced from the pure 12% TSS (total soluble solids) extract (Ext pure) proved to be significantly better than that of the other products.[88]

Commerce: Baobab is a major nontimber forest product (NTFP), that plays a significant role in the lives of communities in the Savannah and its many products (seed oil, leaves, and fruits) constitute a source of income of many rural people in Africa. Baobab products are used in pharmaceutical and cosmetic industries. According to a UNCTAD report,[89] baobab is highly sought after in several market segments such as food and beverages (Germany, France, and the Netherlands), botanical remedies (Germany, France, and the Netherlands), and nutraceuticals as well as natural cosmetics (EU, United States, and Japan). Baobab fruit is an ideal candidate in the functional food market as it is very high in vitamin C and other vitamins and minerals; the powder may be used as a thickener due to its high pectin and fiber content. The import value of the product class of rare edible dried fruit, which includes baobab fruit pulp, grew by 13% in 2003.

The USFDA approved on July 25, 2009 the designation of dried baobab fruit pulp (DBFP) as "GRAS," that is, a substance that is generally recognized as safe, which was based on a submission by PhytoTrade in 2008 to that agency. According to the Federal Food, Drug and Cosmetic Act (Sections 201(2) and 409), any substance that is intentionally added to food as an additive is subject to premarket review and approval by the FDA. This makes baobab a major article of international commerce. The designation of DBFP as GRAS, through scientific procedures, allows for its use as an ingredient in blended fruit drinks and fruit cereal bars at levels of up to 10% and 15%, respectively. Similar classification of baobab as safe food ingredient exists in the European Union.

The global soft drink manufacturer Pepsi launched a proprietary drink based on baobab in Japan in June 2010, and by 2015, five major labels have baobab juice as a major ingredient. Baobab has also been incorporated in the commercial production of jellies, smoothies, energy bars, and assorted pastries and snack foods.

Bissap: Zobo

Overview

Zobo is derived from the calyx and flowers of *Hibiscus sabdariffa*. A variety of fruit drinks made from zobo and other herbs, such as ginger, turmeric, and alligator pepper, are sold in markets in West Africa as a general health tonic for the improvement of general body function, blood circulation, and hypertension. It contains ascorbic acid, β-carotene, anisaldehyde, arachidic acid, citric acid, malic acid, tartaric acid, glycine, betaine, trigonelline, anthocyanins, and flavonoids. It has been shown to possess antioxidant, anti-inflammatory, and hypotensive properties. *Hibiscus* extracts have been shown to lower serum cholesterol in men and women in a dose-dependent manner. It is a considered as a safe caffeine-free, low-tannin tea and beverage. It has a global market as a colorant for herbal teas, with a rising profile and application as a nutraceutical.

Pharmacognostical Profile

Botanical Name: *Hibiscus sabdariffa* L.

Synonyms: *Abelmoschus cruentus* (Bertol.) Walp.; *Furcaria sabdariffa* Ulbr.; *Hibiscus cruentus* Bertol.; *Hibiscus fraternus* L.; *Hibiscus gossypifolius* Mill.; *Hibiscus palmatilobus* Baill.; *Sabdariffa rubra* Kostel.

Related Species: *Hibiscus acetosella* Welw. ex Hiern; *Hibiscus rosa-sinensis*; *Hibiscus cannabinus* L.

Family: Malvaceae

Common Names: Roselle, red sorrel, Zobo, Jamaican sorrel, Indian sorrel, bissap, karkadeh, *Hibiscus* flower

African Names: Hausa: Abin kan iyaka, zobo; Igbo: Okworo-ozo; Yoruba: Amukan; Swahili: Ufuta, ufuta dume

Description: The shrub is an erect, slightly branched with smooth or slightly hispid plant that can grow up to 4 m in height. The stem is glabrous to sparsely pubescent, sometimes sparsely prickly, and green or reddish. It has lobed leaves and big yellow flowers with a purple center. The epicalyx and calyx are fleshy and succulent, bright red, and persistent. The fleshy calyx is situated at the base of the flowers and is about 1.5–2 cm wide and on maturity of the fruit becomes enlarged to 3–3.5 cm. The plant takes about 6 months to mature and it is harvested at the fruiting stage. *Hibiscus* flower, as the harvested product is called, is edible with a sweet-sour taste.



Habitat and Distribution: *Hibiscus sabdariffa* originated from Africa, where it may have been domesticated in Sudan and Northern Nigeria about 6000 years ago, first for its seed and later for leaf and calyx production. However, apparently truly wild plants of *Hibiscus sabdariffa* have been collected in Ghana, Niger, Nigeria, and Angola. It is believed that the vegetable types were introduced to India and the Americas in the seventeenth century. Selection for fiber production took place in Asia, where cultivation is reported from the beginning of the twentieth century, for example, in India, Sri Lanka, Thailand, Malaysia, and Java. Roselle is now found throughout the tropics. In tropical Africa, it is especially common in the savanna region of West and Central Africa. It is often found as an escape from cultivation.[1]



Culinary (Food) Use: Zobo is used throughout West and North Africa as a vegetable and for the preparation of fruit drinks either alone or in a mixture with fruits and herbs.

Ethnomedicinal Uses: It is valued as a general tonic for the improvement of general body function, blood circulation, and hypertension. Leaves are used as a gargle for cough, toothache, and throat inflammation. It is reported as a good relief for coughs, biliousness, and symptoms of plethora. The flowers are applied in wound dressing. The roots are effective for application to abscesses and bronchitis. Calyces are used to produce beverages that serve as a blood tonic and for high blood pressure. Whole dried aerial parts have been used for sexual asthenia, poultice, cough, peristalsis, diuretic, mouthwash, toothache, laxative, boils, bronchitis, conjunctivitis, and to ease childbirth.

Constituents: Many chemical constituents have been isolated from the calyx and flowers of roselle. These include alkaloids, ascorbic acid, β-carotene, anisaldehyde, arachidic acid, citric acid, malic acid, tartaric acid, glycine, betaine, trigonelline, anthocyanins as cyanidin-3-rutinoside, delphinidin, delphinidin-3-glucoxyloside (also known ashibiscin, the major anthocyanin in *H. sabdariffa* flowers), delphinidin-3-monoglucoside, cyanidin-3-monoglucoside, cyanidin-3-sambubioside, cyanidin-3,5-diglucoside; the flavonol glycosideshibiscetin-3-monoglucoside, gossypetin-3-glucoside, gossypetin-7-glucoside, gossypetin-8-glucoside and sabdaritrin; quercetin, protocatechuic acid, pectin, polysaccharides, mucopolysaccharides, stearic acid, and wax.[90,91] The phytosterols campasterol, stigmasterol, ergosterol, β-sitosterol, and α-spinasterol have been reported from the seed oil. The petals yielded 65% (dry weight) of mucilage, which on hydrolysis gave galactose, galacturonic acid, and rhamnose. In addition to these compounds, *Hibiscus sabdariffa* extract (HSE) contains complex polyphenolic acids (1.7% dry weight), flavonoids (1.43% dry weight), and anthocyanins (2.5% dry weight).

Pharmacological Studies: The various biological activities associated with *Hibiscus sabdariffa* can be related to the compounds found in the shrub. These molecules are bioactive in several biological models and are responsible for the pharmacological effects presented by the extracts of this species. Various antioxidant constituents are found in the calyx and flower petals of roselle, such as *Hibiscus* anthocyanins (HA), quercetin, ascorbic acid, steroid glycosides (such as β-sitosteroid glycoside), and protocatechuic acid.

It has antispasmodic, anthelminthic, and bactericidal properties. The antihypertensive and cardioprotective effects of tea made from roselle calyces have been demonstrated in various animal tests, and also in a few clinical tests. The phenolic compound protocatechuic

acid (PCA) isolated from roselle flowers showed antioxidant, antitumor, and hepatoprotective activities. It has been demonstrated to be an efficacious agent in inhibiting the carcinogenic action of various chemicals in different tissues, such as diethylnitrosamine in the liver, 4-nitroquinoline-1-oxide in the oral cavity, azoxymethane in the colon, *N*-methyl-*N*-nitrosourea in glandular stomach tissue, and *N*-butyl-*N*-(4-hydroxybutyl)nitrosamine in the bladder, in murine models. PCA also shows mild cytotoxicity to PC14 and MKN45 human tumor cell lines and induces apoptosis in human leukemia HL-60 cells by means of the reduction of retinoblastoma protein phosphorylation and Bcl-2 expression. Thus, PCA may play a role in dietary chemoprevention.

Hibiscus extracts have been shown to lower serum cholesterol in men and women in a dose-dependent manner. In a clinical study, 42 volunteers were observed over a period of 4 weeks. The volunteers ranged from 18 to 75 years old with a cholesterol level of 175–327 mg/dL. Subjects were randomly assigned to three groups: group I (1 capsule of HSE during each meal), group II (2 capsules), and group III (3 capsules). Serum cholesterol levels were determined at baseline before the study commenced and at 2 and 4 weeks of the treatment period. In general, taking HSE led to a significant decrease in serum cholesterol level in subjects from groups I and II after 4 weeks. After HSE had been administered for 2 weeks, serum cholesterol levels were found to be lower in all groups ($P < .05$ for groups I–III) compared with baseline values by 7.8%–8.2%. A similar response was observed, a reduction in serum cholesterol level by 8.3%–14.4%, after 4 weeks of taking the supplement. It is important to note that the serum cholesterol level for 71% of group II volunteers was significantly lowered with a mean reduction of 12% ($P < .05$). The authors concluded that a dosage of two capsules of HSE (with a meal) for 1 month can significantly lower the serum cholesterol level. The observation of lowered serum cholesterol in these subjects suggests that HSE may be effective in hypercholesterolemic patients.[92] This clinical study validates an earlier result from feeding experiments in hypercholestrolemic rats.[93]

In another clinical study, HSE was shown to possess significant uricosuric effect.[94] The study involved a human model with nine subjects with no history of renal stones (nonrenal stone, NS) and nine with a history of renal stones (RS). A cup of tea made from 1.5 g of dry roselle calyces was provided to subjects twice daily (morning and evening) for 15 days. A clotted blood and two consecutive 24-h urine samples were collected from each subject three times: (1) at baseline (control); (2) on days 14 and 15 during the tea drinking period; and (3) 15 days after the tea drinking was stopped (washout). Serum and 24-h urinary samples were analyzed for uric acid and other chemical compositions related to urinary stone risk factors. The results when analyzed showed that serum parameters were within normal ranges and similar between the two groups of subjects and among the three periods. Vis-à-vis the urinary parameters, most of the baseline values for both groups were similar. After taking the tea, the trend was an increase in oxalate and citrate in both groups and uric acid excretion and clearance in the NS group. In the RS group, both uric acid excretion and clearance were significantly increased ($P < 0.01$). When the fractional excretion of uric acid (FEUa) was calculated, the values were clearly increased in both the NS and SF groups after the intake of tea and returned to baseline values in the washout period. These changes were more clearly observed when the data for each subject were presented individually.[95]

The antihypertensive activity of HSE has been demonstrated in several human and animal studies. Ajay et al. has established the probable mechanisms to explain the pharmacological basis of the observed clinical hypotensive activity of HSE.[96] The study observed the effects of a crude methanolic extract of the calyces of HSE on vascular reactivity in

isolated aortas from spontaneously hypertensive rats. HSE relaxed, concentration-dependently, KCl (high K^+, 80 mM) and phenylephrine (PE, 1 μM)-precontracted aortic rings, with a greater potency against the α_1-adrenergic receptor agonist. The relaxant effect of HSE was partly dependent on the presence of a functional endothelium as the action was significantly reduced in endothelium-denuded aortic rings. Pretreatment with atropine (1 μM), l-NAME (10 μM), or methylene blue (10 μM), but not indomethacin (10 μM), significantly blocked the relaxant effects of HSE. Endothelium-dependent and endothelium-independent relaxations induced by acetylcholine and sodium nitroprusside, respectively, were significantly enhanced in aortic rings pretreated with HSE when compared to those observed in control aortic rings. The results thus demonstrated that HSE has a vasodilator effect in the isolated aortic rings of hypertensive rats. These effects are probably mediated through the endothelium-derived nitric oxide-cGMP-relaxant pathway and inhibition of calcium (Ca^{2+}) influx into vascular smooth muscle cells.

Toxicity: The aerial parts of roselle or zobo or *Hibiscus* flower have been used as a safe tea substitute and nutraceutical for centuries without any manifest toxicity. With the popularity of HS as a long-term food medicine for the management of elevated blood pressure and hypercholesterolemia, it became necessary to investigate any possible toxicity in acute animal models and cohort long-term studies in human subjects. One such study was aimed at the assessment of the potential adverse effects of *H. sabdariffa* extract on sperm morphology and testicular ultrastructure of albino mice. Thirty adult male albino mice were divided into three equal groups and were given (a) distilled water, (b) cold *Hibiscus* aqueous extract, and (c) boiled *Hibiscus* aqueous extract. *Hibiscus* extract was administered orally daily for 4 weeks in a dose of 200 mg/kg body weight/mouse. Twenty-four hours after the last treatment, mice were decapitated and the testes and epididymides were excised and processed for transmission electron microscopy to assess ultrastructural and sperm abnormalities. The results clearly demonstrate that aqueous extracts from dried calyx of *H. sabdariffa*, either cold or boiled, alter normal sperm morphology and testicular ultrastructure and adversely influence the male reproductive fertility in albino mice.[97] Other toxicity studies on experimental animals evaluated the effect of Ha on liver rat liver enzymes and indicated possible hepatotoxicity of prolonged use of HSE.[98] These findings, though not easily transferable to the human situation, tend to suggest that *Hibiscus* extract may pose some human risk on prolonged use at high doses. It is interesting to observe that a later study actually indicated that HSE displayed antihepatotoxic activity when tested against azathioprine-induced acute liver damage.[99]

Commerce: *Hibiscus sabdariffa* still remains a grossly underutilized plant. It is an important industrial crop for its fibers and the demand for roselle fiber is likely to increase as a result of the rising interest in natural, biodegradable fibers. It has a global market as a colorant for herbal teas. Its rising profile and application as a nutraceutical agent makes it a commercially dependable crop. This multipurpose crop provides farmers with food and cash income when other vegetables become scarce. Processing generates additional family income, from which women benefit in particular. The use of roselle as a vegetable or as a beverage should be promoted through research to improve cultivars, husbandry, and postharvest technologies. Applying rigorous quality standards for grading, processing, and packaging will boost competitiveness in the international market. The current market price for HA in the international market is US$ 2350–2450 MT/CIF.

Agriculture: The seedlings for cultivations are collected during thinning, the period of vegetative growth when the plants are 6–8 weeks old, branches of about 50 cm long are picked 2 or 3 times. Calyces are harvested manually 2–3 weeks after flowering, usually 4–6 months after sowing, before the fruit has dried and dehisced. Regular picking

prolongs flowering. The calyces are dried in the shade. When harvested for fiber, stems are cut before flowering, 4–5 months after planting. Fiber quality declines rapidly after the start of flowering. A single roselle plant may yield as many as 250 calyces, or 1–1.5 kg fresh weight. In Africa, average yields are much lower and variable because of environmental conditions and extensive management. Sudan reports an average yield of dry calyces of 93 kg/ha. In Senegal, maximum production of calyx on a dry weight basis is 500 kg/ha. Average fiber yields from roselle are 1.5–2.5 t/ha, depending on cultivar and management. India reported an average yield of 1.9 t/ha for 1997–2001. Reported seed yields range from 200–1500 kg/ha.[1]

Bitter Kola

Overview

Garcinia kola is a medium-sized tree, though it sometimes grows up to 12 m tall and 1.5 m wide. It is a spreading tree with a dense and heavy crown; the bole is straight, the bark is greenish-brown, thick, and smooth. It produces characteristic large fruits (6 cm in diameter), with the size and color of an orange, containing 2–4 brown seeds embedded in an orange-colored pulp. The seeds, fruit pulp, and rind are used in traditional medicine for the treatment of various diseases, including diabetes, laryngitis, and tumors. The constituents can be grouped into three classes: the polyphenols, including alkylated benzophenones, xanthones, and biflavonoids and related compounds, tocotrienol, and the triterpenoids. Kolaviron, the mixture of biflavonoids, benzophenones, and chromanols, as well as other phenolic compounds in *G. kola,* possesses strong antioxidant activities. Several reports on the experimental validation of the antioxidant properties of *Garcinia* are essentially due to kolaviron. An evaluation of the antioxidant properties of garcinoic acid (structurally similar to vitamin E) and its congeners, including investigation of the structure–antioxidative activity relationships, identified a semisynthetic derivative with antioxidant activity that was 18.7 times stronger than DL-α-tocopherol. It has also been shown to inhibit the aflatoxin B1 genotoxicity in human-liver-derived HepG2 cells. The extracts of bitter kola and some of the constituents have been found to be antidiabetic, anticholesterolemic, and antiviral. The *Garcinia* benzophenones have the ability to modulate the epigenetic histone methylation by xenobiotics and therefore have a positive role in the management of chronic inflammation in the aged.

Pharmacognostical Profile

Botanical Name: *Garcinia kola* Heckel

Synonyms: *Garcinia akawaensis* Spirlet.; *Garcinia bergheana* Spirlet

Family: Clusiaceae

Common Names: Bitter kola, false kola, male cola

African Names: Bini: edun; Efik: efiari; Ibibio: efiat; Igbo: akilu, aki-inu, adi, akara-inu, ogolu; Ijaw: okan

Description: A medium-sized tree, *Garcinia kola* has broad leaves, 5–10 cm long, elongated elliptic to broadly elliptic, acute or shortly acuminate, cuneate, leathery, with very distinct resinous canals. It has 10 pairs of lateral veins that run parallel to the margin but not forming a marginal nerve; the midrib is prominent at the undersize; the stalk is

stout, finely hairy in young leaves, about 8 mm long.[100] It bears male and female flowers separately, usually December–March and May–August. Female flowers are yellow and fleshy, globose, 1.5 cm wide; male flowers are smaller but with more prominent stamens (4 bundles), 4 sepals, 4 greenish-white petals. It produces characteristic large fruits (6 cm in diameter), with the size and color of an orange, containing 2–4 brown seeds embedded in an orange-colored pulp.



Habitat and Distribution: Found in moist forests, also cultivated in homesteads. It is distributed throughout West and Central Africa; has been located in Sierra Leone, Ghana, Nigeria, Cameroon, and Congo.

Culinary (Food) Use: Bitter kola is used as a snack and offered to guests with Kola nuts and garden egg as a symbolic welcome fruit.

Ethnomedicinal Uses: It is used extensively in traditional medicine for the treatment of various diseases. The drug is chewed in southern Nigeria and parts of West Africa as a masticatory, in spite of its very bitter taste. The stem bark is used as a purgative and the powdered bark for the treatment of malignant tumors. The sap is used for parasitic skin diseases. The latex (gum) is used internally for gonorrhea treatment and applied externally to fresh wounds. The twigs of *G. kola* can be used as tapers and the roots yield the favorite bitter chew sticks sold in small bundles in local markets in West Africa. The seeds are used to prevent or relieve colic, cure head or chest colds, and relieve cough. The seeds are chewed as an aphrodisiac and the dried nuts for dysentery treatment. The seeds are also used in the treatment of diabetes, bronchitis, and throat infections. The plant has also been employed in the treatment of liver disorders.[101] The peeled stem and twigs are cut into small pieces and placed into bottle of local gin, allowed to "mature" over a couple of days, and drunk as an aphrodisiac. The alcohol is replenished several times until the resultant infusion becomes colorless.

Constituents: *G. kola* and other members of the genus are known to elaborate a complex mixture of phenolic compounds, including biflavonoids, xanthones, and benzophenones.[102–104] The most important constituents of the plant include the antimicrobial benzophenone, kolanone,[105] and biflavonoids based on eridictoyl/taxifolin moiety GB1,

GB2, GB3, kolaflavanone, and garciniflavanone.[106,107] The seeds also contain the chromanols, garcinoic acid, garcinal and their derivatives, as well as tocotrienol.[108]

Pharmacological Studies: *G. kola* has been shown to possess remarkable antihepatotoxic activity against a variety of experimental hepatotoxins, including carbon tetrachloride, 2-acetylaminofluorene, paracetamol, and galactosamine[109–114] and the protection against the accumulation of heavy metals in the liver.[115] Chronic ingestion of *G. kola* seeds caused inhibition of gastrointestinal motility and weight reduction and prevented castor oil-induced diarrhea in rats.[116] Other activities of the biflavonoid mixture include anti-inflammatory, antimicrobial, antidiabetic, and antiviral properties,[117–119] as well as antioxidant and chemoprotective activities.[120] The antiviral activity is quite broad, showed remarkable inhibitory effects against a variety of viruses, including punta toro, pichinde, sandfly fever, influenza A, Venezuelan equine encephalomyelitis, and ebola. The IC_{50} values are in the range of 7.2–32 μg/mL with an MTC of more than 320 μg/mL.[121]

The seed extract and the dried powder have been formulated into various dosage forms, including tablets, lozenges, creams, in vials, and as toothpaste.[122] The biflavonoids also possess antidiabetic activity and inhibited the activity of rat lens aldose reductase.[123] Examination of the liver, kidney, and duodenum of rats fed a diet containing 10% (w/w) dry powdered seeds of *G. kola* for 6 weeks has been reported as revealing some histological alterations in these organs. Studies indicate a possible role in the treatment of dermatological disorders associated with melanin hyperpigmentation. The methanol extract and a *Garcinia* biflavonoid displayed inhibitory activity (>60%) against tyrosinase (EC 1.14.18.1), the rate-limiting enzyme in melanin synthesis.[124]

Kolaviron, the mixture of biflavonoids, benzophenones, and chromanols, as well as other phenolic compounds in *G. kola* possesses strong antioxidant activities. Several reports on the experimental validation of the antioxidant properties of *Garcinia* are essentially due to kolaviron. An evaluation of the antioxidant properties of garcinoic acid (structurally similar to vitamin E) and its congeners, including investigation of the structure–antioxidative activity relationships, identified a semisynthetic derivative with antioxidant activity that was 18.7 times stronger than DL-α-tocopherol.[125] The aqueous extract showed antidiabetic activity in hyperglycemic rats.[126] At a concentration of 200 mg/kg body weight, over a period of 21 days, the extract significantly ($P < 0.05$) decreased the blood glucose level, increased the activity of superoxide dismutase ($P < 0.05$), and that of malondialdehyde ($P < 0.05$). The extract however had no significant effect ($P > 0.05$) on the activity of catalase.

The clinical outcome observations on the phytomedicines prepared from the standardized whole seeds or extracts of *G. kola* seem to support the laboratory findings reported above and the use of the plant as an adaptogen. Its bronchodilatory effect has been evaluated with a clinical study on 19 male adults. The only respiratory parameter changed by 15 g of *G. kola* was a peak expiratory flow rate, indicating a mild bronchodilatory effect.[127] Observational studies at the InterCEDD, Nsukka, Nigeria indicate potential application as a remedy for colic in dysentery, liver disorders, upper respiratory infections, asthma, cough, sore throat, laryngitis, arthritis, menstrual and intestinal cramps, and headache. Topical uses awaiting clinical validation include its use as a wound dressing, as an antiparasitic lotion, and in oral hygiene (as a chewing stick). The possible clinical uses for *Garcinia* based on the analysis of the above studies include its use as an antiviral, antihepatotoxic, and immune booster in cases of flu, liver and respiratory diseases, as an antioxidant, and in the management of diabetes.

Toxicity: No serious adverse effects have been reported following the consumption of *Garcinia*. In response to public health concerns in West Africa about the long-term use

of *Garcinia* and in view of the presence of a complex mixture of phenol compounds in *Garcinia kola* seeds, investigators at University of Ibadan's (Nigeria) College of Medicine evaluated the hepatic, testicular, and spermatozoa antioxidant status in rats chronically treated with *Garcinia kola* seed. It was observed that long-term treatment of *Garcinia kola* had no adverse effect on the spermatozoa characteristics but significantly elevated testosterone concentration when compared to the control group. Improvement of antioxidant systems was accompanied by a significant decrease in malondialdehyde level in the liver, testes, and spermatozoa of *Garcinia kola*-treated rats. Histological observation revealed that chronic administration of *Garcinia kola* had no effect on the liver and testes at all doses when compared with control.[128]

Bitter Leaf

Overview

The bitter leaf is a leafy vegetable obtained from *Vernonia amygdalina* used in the preparation of the West African bitter leaf soup. Its use in food underscores the acceptance of bitterness as a positive taste among Africans. The plant is a shrub or small tree up to 5 m high. The leaves are reputed to be effective remedies for gastrointestinal disorders and as a general tonic. The major constituents include the saponin vernonin, sesquiterpenes vernoleptin and vernodalin, and ubiquitous flavonoid kaempferol. It also contains saponins, steroidal glycosides, flavonoids, and sesquiterpene lactones. The major activities found in many laboratory and clinical studies on *Vernonia amygdalina* include antimalarial, antidiabetic, antioxidant, antihypercholestrolemic, prebiotic, anthelmintic, uterine contractility, anticancer, immune boosting in HIV infections, and anti-inflammatory properties. Several proprietary formulations exist in which *Vernonia* is either the active component or the main ingredient (e.g., Vernonia–Ocimum® manufactured by IHP for diabetes and immune boosting; Edotite®, which contains bitter leaf as the only active pharmacon, is promoted as an anticancer agent). As a functional food, bitter leaf is useful for the treatment and management of metabolic syndrome because of its remarkable antioxidant, anti-inflammatory, and antidiabetic properties. It could also be useful in moderate hypertension, immune boosting, and as a chemoprotective agent for cancers.

Pharmacognostical Profile

Botanical Name: *Vernonia amygdalina* Del.

Synonyms: *Bracheilema paniculatum* R.Br.; *Cacalia amygdalina* Kuntze.; *Decaneurum amygdalinum* DC.; *Cheliusia abyssinica* Sch.Bip. ex Walp.

Family: Compositae

Common Name: Bitter leaf

African Names: Ashanti: mponasere; Bini: oriwo; Ewe: krepi agbo, avenya (Togo); Fanti: bowen; Fulani: siwakewi, dakuna (Eguinea); Ga: akpa gbo; Hausa: shiwaka; Igbo: olugbu, onugbu; Malinke: kosa finna; Mende: njenyani; Twi: awonwene; Wolof: ndumburghai; Yoruba: ewuro, e jije

Description: A shrub or small tree up to 5 m high. The leaves (15 × 5 cm) are simple and entire (or minutely toothed), obovate-oblanceolate, finely glandular below, and displaying

few lateral nerves. The flowers occur in copious corymbose panicles, white, fragrant, and usually bee-infested. The species can be easily differentiated from the wild-growing *V. colorata* by the hairy leaves of the latter.[1]



Habitat and Distribution: The plant grows in coastal savanna, but it is often cultivated in many parts of the continent as an edible vegetable. It is distributed from Sudan in the north to South Africa.

Culinary (Food) Use: Bitter leaf is used as a leafy vegetable for the preparation of the West African bitter leaf soup.

Ethnomedicinal Uses: The leaves are reputed to be effective remedies for gastrointestinal disorders and as a general tonic. An aqueous decoction of the leaves has been used for the treatment of fevers and diabetes. The dried leaves are chewed for the same purpose, and by pregnant women to check nausea. The fresh leaves are, however, believed to be abortifacient. The bitterness of the leaves is usually reduced by boiling, and soaking in water followed by several washings with fresh water. The peeled stem is used for cleaning the teeth and the bark is administered for venereal diseases and for diarrhea. The plant is added in very minute quantities in several remedies, but it is not clear whether it is used to impart a bitter taste to the medication or included for the therapeutic purposes. The leaves are ingredients in purgative enemas, diuretic mixtures, anthelmintic preparations, and topical lotions for parasitic skin diseases. The bitterness of the leaves is often exploited by nursing mothers to assist in weaning babies by rubbing the juice on their breasts. Soup prepared with washed leaves is believed to improve lactation. It is used during labor to facilitate childbirth. It is used with the leaves of *Psidium guajava* for the treatment of hypertension and kidney problems. In Rwanda, it is added to local sorghum beer "ikigage" to increase the potency and for medicinal purposes. Other traditional medicinal uses of this plant in Africa include treatment of malaria, diabetes, pneumonia, tonsillitis, fever, jaundice, anemia, ascariasis, and gastrointestinal disorders. Modern processed preparations by herbal manufacturers advocate its use as treatment for emesis, nausea, loss of appetite, dermatitis, dysentery and other gastrointestinal tract

disorders, and type 2 diabetes, and management of arthritis, gingivitis and toothache, and inflammatory diseases.

Constituents: *Vernonia* contains saponins, steroidal glycosides, flavonoids, and sesquiterpene lactones.[129] The major constituents include the saponin vernonin, the sesquiterpenes vernoleptin and vernodalin, and the ubiquitous flavonoid kaempferol.

Pharmacological Studies: Vernonin has been shown to exert hypotensive activity and mild cardiotonic effects when injected in dogs. A leaf extract of the plant reduced the rate and force of contraction of the isolated frog heart, and in cats caused a marked fall in blood pressure, as well as reduction in heart rate; it also caused a strong stimulation of the isolated rabbit intestine.[130] The sesquiterpene lactones have *in vitro* cytotoxic activity against KB tumor cells and Wilme's myeloma.[131] The extract of the leaves have broad-spectrum antimicrobial activity and has been shown to induce abortion in goats. The methyl alcohol extract of the leaves when administered to 12–13 pregnant mice caused abortion within 24 h of the least dose in a 3-day regimen.[132] Toyang and Verpoorte have published a good review that summarized the various uses, phytochemistry, and pharmacological activities of *Vernonia* species.[133]

The major activities found in many laboratory reports and clinical studies on *Vernonia amygdalina* include antimalarial, antidiabetic, antioxidant, antihypercholestrolemic, prebiotic, anthelmintic, uterine contractility, immune boosting in HIV infections, and anti-inflammatory properties.

Toxicity: *Vernonia amygdalina* is consumed throughout West and Central Africa as a vegetable and is generally considered as nontoxic, but excessive consumption of the leaves is purgative. In a chronic toxicity study, rats were fed with up to 75% (w/w) powdered leaves mixed with grower mash for 65 days and at the end of the study the only gross change observed was the lightening of the skin of the rats in the treatment group versus the control group.[134] The LD_{50} of the related species *V. colorata* in mice is about 10 g/kg.

Boscia

Overview

Boscia senegalensis is a stout shrub that is highly valued as a famine food throughout the Sahel region. During the dry season with extreme aridity, it shrinks to a scrawny shrub less than 2 m tall, but in favorable environments, it soars several times that height and becomes almost treelike with a rounded, spreading crown. In at least a dozen countries, at times people virtually live off Aizen fruits, seeds, roots, and leaves. It is used as a food condiment and is remarkable for its glucosinate content. It is a good source of calcium, phosphorus, iron, protein, and vitamin B. The long processing time is probably indicative of possible toxicity.

Pharmacognostical Profile

Botanical Name: *Boscia senegalensis* Lam.-Holl.
Synonyms: *Boscia firma* Radlk.; *Boscia hypoglauca* Gilg.; *Boschia octandra* Hoscst. ex Radlk.
Family: Capparaceae
Common Names: Aizen or mukheit

African Names: Bambara: bere; Bargami: kungassa; Fulani: anzagi; Hausa: anza, hanza, dilo; Songhai: horregna; Temajegh (Tuareg): tandeni, tandomei; Wolof: diendoun, ndiandam

Description: *Boscia senegalensis* occurs as a stout shrub or short tree, with black stem, up to 5 m high. The leaves are broad, elliptical to ovate with 5–6 pairs of prominently looped lateral nerves. The flowers are greenish, sweet-scented, and are borne in short dense racemes. The fruits are spherical, sometimes warted, up to 2 cm in diameter. Each fruit usually has one or two greenish seeds, which look like and are used like peas. In extreme aridity, aizen shrinks to a scrawny shrub less than 2 m tall, but in favorable environments it soars several times that height and becomes almost treelike with a rounded, spreading crown. It has a remarkable leaf structure, which contributes to the plant's in-built drought tolerance: the cuticle is up to 20 µm thick, the stomata are sunk in deep cavities, and each stomate has thickened walls and a protective armoring of papillae.



Habitat and Distribution: The plants occur in the drier parts of the continent. Dalziel listed it as being present "in barren and fire-scorched soil." It is distributed from Mauritania to northern Nigeria.

Culinary (Food) Use: The acrid-tasting fruit is edible after soaking in water for about a week. It is also valued as a cereal substitute. Throughout the Saharo-Sahelian zone, they are such common items of diet that they are sometimes described as desert dwellers' staples. They are important famine-time foods. And when roasted, they also substitute for coffee.

Ethnomedicinal Uses: The leaves and berries are commercially available in many parts of northern Nigeria and Sudan as food condiments for soups in times of scarcity. The leaves are used in the preparation of malaria remedy and for the treatment of jaundice, fungal infections, and venereal diseases. It is applied externally for wound dressing. The fruits and roots are used as aphrodisiac, and the root decoction is used for stomachache and to facilitate labor.

Constituents: The plant contains alkyl glucosinolates[135] and the alkaloids, stachydrine, and hydroxystachydrine.[136] The genus has been shown to elaborate several flavonoids,[137] sesquiterpenes and their glycosides,[138] sulfur compounds,[139] and lipids.[140] It is a good source of calcium, phosphorus, iron, and vitamin B. It is rich in protein, containing about

30%–35% in the fruit. The leaves have been shown to contain lignans, diepoxylignans, epoxylignans, and neolignans.[141]

Pharmacological Studies: The plant possesses antimicrobial and antifungal activities.[142–144] It has also been shown to be an effective uterine stimulant.[145] It possesses antioxidant and anti-inflammatory properties. A related species *B. salicifolia* has been evaluated for its sweetening properties.

Buchu

Overview

Buchu is one of the best-known medicinal plants of Africa. It is used traditionally as a general tonic and for the treatment of urinary tract infections and stomach troubles. In modern medicine, it has been found useful as diuretic, antispasmodic, antipyretic, antibacterial, antifungal, and antiseptic, and for the treatment of kidney and urinary tract infections, rheumatism, gout and bruises, cold, cough, fever, hematuria, prostatitis, cholera, stomach ailments, and calculus. Buchu essential oil and the flavonoid content of the aromatic leaves are considered responsible for the medicinal effects ascribed to buchu. It is also valued for its unique fragrance and flavor, which has been used to blend drinks and food substances. Buchu used in commerce is mainly derived from *Agathosma betulina* known as round-leaf or short buchu. It is sometimes adulterated with leaves of *Agathosma crenulata*, which may contain high levels of pulegone in the essential oil, thus making the product potentially unsafe for human consumption.

Pharmacognostical Profile

Botanical Name: *Agathosma betulina* (P.J. Bergius) Pillans

Synonyms: *Barosma betulina* (P.J. Bergius) Bartl. & H.L. Wendl.; *Barosma orbicularis* Sweet; *Bucco betulina* Schult; *Hartogia betulina* P.J.Bergius

Related Species: *Agathosma crenulata* (L.) Pillans

Family: Rutaceae

Common Names: Buchu, diosma

African Names: Khoi: buchu; Afrikans: boegoe, rondeblaarboegoe; S.A: Bucco, bookoo; Xhosa: ibuchu

Description: *Agathosma betulina* is a resprouting, broad-leaved aromatic shrub with erect woody stems reaching 2 m height, but low-growing and prostrate varieties also occur. The leaves are of pale green color, leathery and glossy, with a blunt, strongly curved tip and a finely toothed margin. Round pellucid oil glands are conspicuously scattered throughout the leaf, along the margins and lower surfaces. They are strongly aromatic, usually opposite, ericoid, often crowded, simple, entire, from 0.5 to 3.5 cm long. The star-shaped flowers are produced in terminal clusters, 0.7–2 cm diameter, with five white, pink, red, or purple petals. The brownish fruits are five chambered. The two related buchu plants can be differentiated by the shape of the leaves: *A. betulina* is described as "round-leaf buchu," whereas *A. crenulata* is known as "oval-leaf buchu." The later species has been described as a pungently aromatic, woody, single-stemmed shrub, which reaches a height of 2.5 m. The glossy, dark green leaves are more than twice as long as they are broad with many oil

glands throughout. The delicate stems bear one to three, relatively large white or mauve flowers in the leaf axils.[146]

Habitat and Distribution: Buchu is a southern African plant that appears to be naturally restricted to the Cedarberg Mountain range of the Western Cape Province of South Africa. *Agathosma betulina* is particularly adapted to dry conditions, and can be found on sunny hillsides where other crops will not succeed. It can be found on the rocky sandstone slopes of the north western Cape region. *A. crenulata* grows on the damp lower and middle slopes and valleys, from Ceres to Swellendam (South Africa).

Ethnomedicinal Uses: Buchu is a highly valued traditional medicine for the treatment of inflammatory conditions and kidney and urinary tract infections. It has also been used as an appetite stimulant, digestive, antispasmodic, and carminative, and for the treatment of coughs, cystisis, prostatitis, influenza, colds, hangover, rheumatism, and gout. Buchu is a general restorative tonic in African ethnomedicine. It is also an effective insect repellant. In the pharmacopeias, buchu is categorized as a diuretic and urinary tract antiseptic. Herbal medicine shops include the plant in formulations to treat arthritis, cellulite, cystitis, diarrhea, flatulence, kidney infections, nausea, rheumatism, and wounds.

Constituents: Both commercially important species of *Agathosma* yield essentials oils (1%–2% w/w). *A. betulina* is characterized by the dominant presence of diosphenol in the oil (ca. 40% of total oil) with limonene, menthone, L-pulegone (<5%), and (ψ)-diosphenol (anisomer of diosphenol), whereas *A. crenulata* elaborates high pulegone content of about 50% with near total absence of the diosphenol found in *A. betulina*. Buchu also contains flavonoids, diosmin, diosmetin, quercetin-3,7-diglucosides, and rutin. It has been reported that the characteristic blackcurrant smell and flavor of buchu oil is due to the presence of sulfur-containing minor compounds (8-mercapto-*p*-menthan-3-one). The two species can be standardized and qualitatively differentiated easily by liquid and gas chromatographic techniques with or without coupling to a mass spectroscopy based on the analysis of the composition of the oils. The use of vibrational spectroscopy has also been reported for the quality assessment of the two commercially important species.[147]

Pharmacological Studies: The essential oil obtained from *A. betulina* has been shown to inhibit 5-lipoxygenase enzyme, which is involved in the inflammation process (IC_{50} = 35.2 μg/mL).[148] The data clearly indicate that the *Agathosma* essential oil blocks the synthesis of 5-LOX products *in vitro*. Since leukotrienes, for which 5-LOX is the key enzyme, are considered to be involved in the initiation and maintenance of a variety of inflammatory diseases, it may be reasonable to state that the inhibition of leukotriene synthesis may, at least in part, be responsible for the anti-inflammatory action of these species. The spasmolytic activity on guinea pig ileum by the same species has been demonstrated, which is indicative of apparent blockage of calcium channels. Although buchu contains flavonoids, studies have shown that the plant has only weak antioxidant activity in the DPPH assay, both species having IC_{50} values >100 μg/mL. Neither was found to exhibit radical-scavenging activity equivalent to that of the standard ascorbic acid (IC_{50} value of 2.47 ± 0.178 μg/mL).

The antimicrobial activity of various extracts of buchu has been investigated by several scholars, which showed that buchu possesses moderate antimicrobial properties. An *in vitro* antimicrobial study of *A. betulina* extracts (water, dichloromethane:methanol, and methanol) on seven pathogenic microorganisms, namely, *Listeria monocytogenes*, *Pseudomonas aeruginosa*, *Candida albicans*, *Escherichia coli*, *Proteus vulgaris*, *Staphylococcus aureus*, and *Enterococcus faecalis* using the MIC microplate assay showed that the dichloromethane:methanol extracts had greatest activity with MIC values ranging between 3 and 6 mg/mL.[149] The study also

evaluated the effect of "buchu" extracts on the growth and development of biofilms using the crystal violet (CV) assay. The dichloromethane:methanol extracts prevented the attachment of bacteria to the polyvinyl chloride surface; however, exposure of *Candida albicans* to the extracts enhanced attachment and subsequent biofilm formation. The growth and development of a preformed biofilm was also inhibited, but to a lesser extent.[43]



An evaluation of the efficacy of "buchu" oil applied topically to treat pain resulting from muscle damage has been conducted by the Research Unit of Exercise and Sports Medicine, University of Cape Town, South Africa. In the study, 30 male participants did a bout of exercise using their nondominant arm with the intention of causing exercise-induced muscle damage. The results from the double-blind placebo-controlled trial indicated that the group treated three times daily with buchu gel showed a reduction in swelling, which may be ascribed to the anti-inflammatory properties of buchu.

Toxicity: The extracts of *A. betulina* and *A. crenulata* were shown to be nontoxic at the concentrations tested (IC_{50} values > 100 µg/mL) using the MTT (3-[4,5-dimethyl-2-thiazolyl]-2,5-diphenyl-2*H*-tetrazolium bromide) cellular viability assay. In the same assay, the essential oils proved to exhibit higher toxicity at the concentration tested, both having IC_{50} values of <0.0001 µg/mL when compared to the control.[150] The compound *cis*-isopulegone present in both species may contribute to the observed toxicity. *R*-(+)-pulegone is known to be a hepatotoxic compound, where large oral doses have been shown to deplete glutathione, which is needed in one of several biological detoxification steps. This depletion along with excess pulegone leads to centrilobar hepatocellular necrosis.

Formulation and Dosage Forms: The leaves are usually air-dried and may be steam-distilled to obtain the oil. Apart from its use in the dietary supplement industry, it is a major ingredient in the flavor and fragrance industry where buchu is used to enhance fruit flavors. It is particularly used to boost blackcurrant-like flavors. Its fragrance has a minty camphoraceous, sweet berry, catty, tropical guava, apricot and peach, green herbal taste. The oil is also used in perfumes and colognes. Several proprietary products exist in which buchu is used either alone or in combination with ginger, *G. kola*, *Curcuma longa* for arthritis, and with *G. kola* and *Cola nitida* (InterCEDD Health Products) as a "hangover" tonic.

Commerce: The two species of *Agathosma* are articles of international trade. The crude drug as well as the volatile oils are traded extensively. Herbalists and trade associations in

South Africa export buchu to Europe, especially Germany and France. Although producer prices have fluctuated wildly in recent years, the demand for this crop has been stable in the last decade. According to the Market News Service (MNS) Bulletin on Medicinal Plants and Extracts—2011, the wholesale price of dried leaves of buchu is 38.36 USD/kg on CIF terms.

Agriculture: Buchu is restricted to South Africa and is a typical component of the fynbos vegetation of the Cape region. Although some cultivation has been embarked on since the 1970s to raise improved varieties with more desirable properties, most of the commercial products are still wild-crafted. Recent efforts in crop development have resulted in buchu now being a viable option for small-scale farming. Recently, growers experienced severe losses, ascribed to a soil-borne disease. The bioequivalence of some of the hybrids and cultivars is yet to be determined so it is therefore important that only products obtained from *A. betulina* should be used for oral consumption because the possible adulteration with other related species that may have serious health consequences.[151]

Bush Cane

Overview

Costus is wild-growing succulent plant chewed to quench thirst in the forest and on farms. The plant contains several triterpenoids. The extracts of the aerial parts have shown anti-inflammatory activity in laboratory animals. It is interesting to note that the methanolic extract exhibited a biphasic antihyperglycemic activity. At 200 mg/kg body weight, p.o., it decreased the blood glucose level by 50% in streptozotocin (STZ)-induced hyperglycemia in male rats in 60 min post dosing. However, at doses above 200 mg/kg body weight, p.o., an increase in the blood glucose level was observed and potentiated the effect of STZ. At 10 g/kg, the extract induced about 98% glucose uptake in differentiated 3T3-L1 adipocytes when compared with insulin (340 nm). The extract also induced expulsion of whole fetuses still enveloped within the placental membrane at the 3rd trimester of pregnancy in rats. Costus root oil causes contact dermatitis, and sensitivity to the oil is employed as a diagnostic agent for examining delayed, cell-mediated immune system reactions.

Pharmacognostical Profile

Botanical Name: *Costus afer* Ker

Synonyms: *Costus anomocalyx* K.Schum.; *Costus littoralis* K.Schum.; *Costus oblitterans* K.Schum.; *Costus prodigiosus* A. Chev.; *Costus pterometra* K.Schum.

Family: Costaceae

Common Names: Ginger lily, bush cane

Local Names: Hausa: kakizuwa; Igbo: okpete; Yoruba: tete-egun; Efik: mbritem

Description: A herbaceous plant of up to 3 m high in rich soil, with succulent unbranched stem. The leaves are smooth, velvety-green, and large; lanceolate, up to 20 cm long and 6.5 cm broad. Long pointed at the apex and narrowly rounded at the base. The veins are parallel with the midrib. The leaves are borne on the stem bracts. The flowers are tubular, yellowish or pink, attached to a swollen terminal bulb. It has a tubular calyx with three

blunt lobes. The corolla is tubular, unsymmetrical, and with three yellowish or pinkish lobes.



Habitat and Distribution: It is found growing wild in secondary forests and more so in the wetter areas. The species is limited to the rainforest and deciduous forests. It is widely distributed on the west coast, in the Nile Valley, and parts of Zimbabwe.

Culinary (Food) Use: Costus is a wild plant chewed as a thirst quencher.

Ethnomedicinal Uses: The succulent stem is chewed as a remedy for cough and a tea made from the dry aerial parts is used for treating hypertension. The root decoction is administered for the treatment of sleeping sickness. The plant is also used for the treatment of diabetes mellitus. An infusion of the whole plant is taken as stimulant and aphrodisiac. The root extract is used for the treatment of stomachache. The rhizome is applied as a paste for skin eruptions and inflammation. The stem, stripped of the leaves and bark, is used to suppress nausea.

A related species *C. schlechteri* has been cited for the treatment of diabetes. The leaves of another species, *C. spectabilis*, are chewed and swallowed for the treatment of pyrexia.[152] In Tanzania, the juice from the stem of *Costus* is used as an anthelmintic alone or in combination with the juice of *Dissotus rotundifolia*, or the stalk of *Aframomum* species. *Costus lucanusianus* is used in the Côte D'Ivoire for the treatment of threatened abortion.[153]

Constituents: The genus *Costus* is rich in steroidal saponins and sapogenins.[154] The rhizome of the subject species has been shown to contain various sapogenins, namely, diosgenin, stigmasterol, and costugenin.[155] The rhizome of the Asian species *C. speciosus*, in addition to the presence of saponins and sterols, contains aliphatic hydroxyl ketones, benzoquinones, and α-tocopherolquinone.

Pharmacological Studies: Extracts of the aerial parts and rhizome have been shown to possess anti-inflammatory activity. Extract of *C. lucanusianus* exhibits uterine-relaxant activity. The root oil from *Costus* causes contact dermatitis and sensitivity to the oil is employed as a diagnostic agent for examining delayed, cell-mediated immune system reactions. In lung cancer patients, it was found that the incidence of positive reactions to *Costus* root oil decreased with the progress of the cancer. The percentage of lung cancer patients who survived was significantly greater for positive than negative patients. It has also been established that patients with localized cancer showed no impairment of sensitivity to *Costus* root oil. The oil has also been shown to inhibit the growth of transplanted

tumors in sensitized BALB/c mice. The *Costus* oil sensitivity is believed to be due to several sesquiterpenes found in the plant. An analysis of cross-reactions in Costus-sensitive patients has revealed that the most active sesquiterpene lactones are the ones with lesser number of oxygenated substituents close to the α-methylene-γ-butyrolactone ring.

The antifungal activity of *C. speciosus* has been shown to be due to the presence of methyl ester of *p*-courmaric acid. The methanolic extract exhibited a biphasic activity antihyperglycemic activity.[156] At 200 mg/kg body weight, p.o., it decreased the blood glucose level by 50% in streptozotocin-induced hyperglycemia in male rats in 60 min post dosing. However, doses above 200 mg/kg body weight, p.o., caused increase in blood glucose level, potentiating the action of STZ. At 10 g/mL, the extract induced about 98% glucose uptake in differentiated 3T3-L1 adipocytes when compared with insulin and also induced expulsion of whole fetuses still enveloped within the placental membrane at the 3rd trimester of pregnancy in rats.

Bush Mango: Ogbono

Overview

The African bush mango or dika tree consists of two closely related species of *Irvingia*, *Irvingia gabonensis* (*ugiri*) and *Irvingia wombolu (adoh). Irvingia gabonensis* has sweet, edible fruit pulp while the fruit of *Irvingia wombolu* (*adoh*) is bitter. Irvigia is a slow-maturing plant, taking 10–15 years for a tree to start bearing fruits. The seeds from both species are traded as ogbono in West African markets and used as soup thickeners for the preparation of the popular ogbono soup. The seeds resemble smooth walnuts, which can be eaten raw or roasted. The seeds yield fat (40–75 g/100 g) called dika fat, which consists of lauric acid 20%–59%, myristic acid 33%–70%, palmitic acid 2%, stearic acid 1%, and oleic acid 1%–11%. The plant is a good source of vitamin C. The pulp contains zingiberene and α-curcumene, ethyl and methyl esters of cinnamic acid, dodecanal, and decanol, which are the main flavor components and are responsible for imparting spicy-earthy, fruity, and wine-yeast flavor notes. Ogbono seeds have been shown by clinical studies to possess antiobesity and anticholesterolemic properties. The male fertility enhancement activity of *Irvingia* has been found to be comparable with that of proviron using enzyme immunoassay method, which was done by the reaction of antibody with serum testosterone and testosterone label, magnetic solid-phase separation, and color development step. Commercial formulation of African bush mango is available in America, Europe, and Japan for the treatment of obsesity.

Pharmacognostical Profile

Botanical Name: *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.

Synonyms: *Irvingia barteri* Hook.f.; *Irvingia caerulea* Tiegh.; *Irvingia duparquetii* Tiegh.; *Irvingia erecta* Tiegh.; *Irvingia griffonii* Tiegh.; *Irvingia hookeriana* Tiegh.; *Irvingia platycarpa* Tiegh.; *Irvingia tenuifolia* Hook.f.; *Irvingia velutina* Tiegh.; *Mangifera gabonensis* Aubry-Lecomte ex O'Rorke.

Related Species: *Irvingia wombolu* Vermoesen (APG = *Irvingia tenuinucleata* Tiegh.); *Irvingia excelsa* Mildbr.

Family: Irvingiaceae

Common Names: African bush mango, dika bread, dika bread tree, dika nut, wild mango, sweet bush mango, ogbono

African Names: Igbo: ugiri, ogbono, odika; Yoruba: apon, oro; Hausa: biri, goron; Cameroon: etima; Gabon: oba; Ivory Coast: odika, ogbono, sioko; Sierra Leone: bobo; Zaire: meba, mueba

Description: The genus *Irvingia* comprises seven species, six occurring in tropical Africa. Two of the species, *Irvingia gabonensis* (*ugiri*) and *Irvingia wombolu* (APG = *Irvingia tenuinucleata* Tiegh.) are closely related and difficult to distinguish from each other. *Irvingia gabonensis* has edible fruit pulp while that of *Irvingia wombolu* (*adoh*) is bitter and inedible. The seeds from both species are used as soup thickeners in West Africa. Both species are called bush mango but *Irvingia gabonensis* is referred to as rainy season bush mango and *Irvingia wombolu* is called dry season bush mango to reflect their respective fruiting periods. They can also be differentiated in commerce as sweet bush mango for *I. gabonensis* and bitter bush mango for *I. wambolu*.

Sweet African bush mango is a small to large tree up to 40 m tall; the bole generally straight, up to 100 cm in diameter, with buttresses up to 3 m high; outer bark smooth to scaly, gray to yellow-gray, inner bark yellow, fibrous; crown spherical or taller than wide, dense. Leaves alternate, simple, and entire; stipules up to 4 cm long, unequal, forming a cone protecting the bud, caducous, leaving an annular scar on the branches; the petiole up to 5 mm long; blade elliptical, 4.5–8 cm × 2–4 cm, base cuneate, apex acute or indistinctly acuminate, thinly leathery, pinnately veined. The inflorescence occurs as an axillary panicle up to 9 cm long. Flowers are bisexual, regular, 5-merous, small; the pedicel up to 5 mm long; sepals free, 1–1.5 mm long; petals free, 3–4 mm long, yellowish white; stamens 10, inserted below disk, free, equal, filaments 4–5 mm long; disk 1.5 mm in diameter, bright yellow, nectariferous; ovary superior, two-celled, style 1–2 mm long. Fruit is ellipsoid to cylindrical drupe, occasionally nearly spherical, slightly laterally compressed, 4–6.5 cm × 4–6.5 cm × 3.5–6 cm, smooth, green when ripe; pulp bright orange, soft, juicy, sweet to slightly bitter, with a few weak fibers, stone woody, one-seeded. Seed usually 2.5–4 cm × 1.5–2.5 cm × ca. 1 cm in size.[4]



Habitat and Distribution: Three centers of genetic diversity in *Irvingia gabonensis* have been identified to be southern Cameroon, south-eastern Nigeria, and central Gabon. *Irvingia gabonensis* prefers moist lowland tropical forest below 1000 m altitude and with annual rainfall of 1500–3000 mm and mean annual temperatures of 25–32°C. *Irvingia gabonensis* is better adapted to acid Ultisols in high-rainfall areas than to less-acidic Alfisols; it

prefers well-drained sites. Often 2–3 trees grow together and in some areas it is reported to be gregarious. The plant is indigenous to the humid forest zone of the Gulf of Guinea from western Nigeria east to the Central African Republic, and south to Cabinda (Angola) and the westernmost part of the Democratic Republic of the Congo (DRC); it has also been found occurring in São Tomé et Príncipe. The presence of *Irvingia gabonensis* is often associated with former human habitation. The bigger *Irvingia* species, *Irvingia excelsa* Mildbr., is somewhat restricted to the rainforest of Cameroon and Gabon, while *Irvingia robur* Mildbr. and *Irvingia smithii* Hook.f. are found co-occurring with *I. gabonensis* throughout the region.

Culinary (Food) Use: Ogbono (ugiri) seeds are used as soup thickeners in West Africa. An edible oil is extracted from the seed that is also used in cooking. The fruit of *Irvingia gabonensis* is juicy and sweet and eaten fresh like mango. It also makes a refreshing tonic drink. Unlike the fruit pulp of most other *Irvingia* spp., which is bitter, the pulp of *Ugiri* has been used for the preparation of juice, jelly, jam, and wine and can be fermented sometimes to yield an alcoholic beverage.

Ethnomedicinal Uses: All parts of the plant are used in traditional medicine. The seed is used for the preparation of a very slimy soup given to nursing mothers to prevent postpartum weight gain. Dika fat is solid at ambient temperatures and has been used as a substitute for cocoa butter in beverages and in cosmetics. The stem bark has been used for dysentery. It is used to increase male fertility, yellow fever, scabies, and skin diseases. The plant has also been used for the treatment of liver diseases, gonorrhea, body pain, gastrointestinal diseases, diarrhea, edema, male sexual dysfunction, and toothache.

Constituents: *Irvingia* is valued for its edible seeds and fruit pulp. The seeds yield fat (40–75 g/100 g) called dika fat, which consists of lauric acid 20%–59%, myristic acid 33%–70%, palmitic acid 2%, stearic acid 1%, and oleic acid 1%–11%. The nutritive value of the kernels per 100 g edible portion is water 4 g, energy 2918 kJ (697 kcal), protein 8.5 g, fat 67 g, carbohydrate 15 g, Ca 120 mg, Fe 3.4 mg, thiamine 0.22 mg, riboflavin 0.08 mg, niacin 0.5 mg. The pulp yields about 75% juice, rich in vitamin C, and wine produced from it was found to be of good color, mouthfeel, flavor, and general acceptability. The pulp contains zingiberene and α-curcumene, ethyl and methyl esters of cinnamic acid, dodecanal, and decanol, which are the main flavor components and are responsible for imparting spicy-earthy, fruity, and wine-yeast flavor notes. The nutritive value of the fruit pulp per 100 g edible portion is water 81 g, energy 255 kJ (61 kcal), protein 0.9 g, fat 0.2 g, carbohydrate 15.7 g, Ca 20 mg, P 40 mg, Fe 1.8 mg, ascorbic acid 7.4 mg.

Pharmacological Studies: The stem bark was found to have analgesic effects in tests with mice. Aqueous extracts of the leaves have caused a reduction in intestinal motility in test animals. A nutritional evaluation related to the performances of growth and the analysis of increasing amounts of dika nut fat (0%, 5.1%, 7.34%, and 13.48%) in young Wistar rats has shown that increasing amounts of dietary *Irvingia gabonensis* fat in correlation with increasing myristic acid (23.53%–58.86%) modifies cholesterol metabolism and increases the concentration of HDL cholesterol without any change in the quantity of the LDL receptor.[157] Clinical observational studies in humans have also shown that the addition of a supplement of 4 g/day of "dika bread" to the diet of type 2 diabetes patients for 1 month reduced plasma glucose and lipid levels. There was remarkable reduction in the LDL + VLDL cholesterol and triglycerides levels, while increasing the levels of beneficial HDL cholesterol. The three ATPases of the erythrocyte membrane of the diabetic patients were significantly lower than in normal subjects.[158] The use of African bush mango for treatment of obesity has been established by several laboratory and clinical studies.[159,160] In a double-blind randomized study involving 40 subjects (mean age 42.4 years), 28 subjects received *Irvingia gabonensis* (IG) (1.05 g three times a day for 1 month) while 12 were on

placebo (P) and the same schedule. During the 1-month study period, all subjects were on a normocaloric diet evaluated every week by a dietetic record book. At the end, the mean body weight of the IG group was decreased by 5.26 ± 2.37% ($P < 0.0001$) and that of the placebo group by 1.32 ± 0.41% ($P < 0.02$). The difference observed between the IG and the placebo groups was significant ($P < 0.01$). The obese patients under *Irvingia gabonensis* treatment also had a significant decrease of total cholesterol, LDL cholesterol, triglycerides, and an increase of HDL cholesterol. On the other hand, the placebo group did not manifest any changes in blood lipid components.[109] The male fertility enhancement of *Irvingia* has been evaluated in a study in which hormonal parameters of male guinea pigs were investigated and compared with that of proviron using enzyme immunoassay method, which was done by the reaction of antibody with serum testosterone and testosterone label, magnetic solid-phase separation, and color development step. The aqueous extract of the seeds (50–400 mg/kg) caused a statistically significance increase ($P < 0.05$ ANOVA) of testosterone in male guinea pigs, from (2.70 ± 0.26) ng/mL to (3.10 ± 0.42) ng/mL on the 7th day and to (3.30 ± 0.48) ng/mL on the 28th day of the administration of the extracts. The highest increase was (3.30 ± 0.48) ng/mL, being obtained after 28 days of treatment. These effects were similar to that of proviron, which was (2.80 ± 0.28) ng/mL and (3.00 ± 0.41) ng/mL on the 7th and 28th day of treatment, respectively.[161]

The extracts of the leaves and roots showed significant antimicrobial activities that were found comparable to those of gentamicin and tioconazole used as controls.[162] The mutagenicity of dika nut as evaluated by Ames assay, *in vitro* and *in vivo* chromosomal aberration test, and *in vivo* micronucleus assay did not reveal any genotoxicity of the extract. The results of a subchronic toxicity study suggest that the no-observed-adverse-effect level (NOAEL) for *I. gabonensis* extract (IGOB131) was greater than 2500 mg/kg /day, the highest dose tested.[163]

Commerce: Kernels of *Irvingia gabonensis* are valuable articles of trade domestically and between countries in West and Central Africa. There has been a recent increase in demand due to international trade due to its use in the preparation of an effective weight loss dietary supplement. Domestication of this species offers great opportunity for the sustainability of production. Few plantations exist in Nigeria and Cameroon but these are hardly sufficient to meet the growing demand and have resulted in substitutes from Asia and fake products containing ordinary mango. ICRAF (cited in Ladipo)[164] reported that in 1975 the market for kernel products was worth in the region of US$ 50 million. The market has been growing since then. The global trade on raw dika nuts and products was estimated at about US$ 165 million in 2010.

Agriculture: *Irvingia gabonensis* has a slow growth on planting but gradually picks up. It is mainly propagated by seed. Germination of *Irvingia gabonensis* seeds takes more than 14 days and they should first be extracted from the fruit and dried for at least 2 days. A germination rate of 80% can be reached in this way. Methods of vegetative propagation through the rooting of leafy stem cuttings under mist have been developed, and micropropagation, grafting, and marcotting experiments have yielded good results. Preliminary results show that plants from bush mango marcotts can fruit 2–2.5 years after transplanting.

Formulation and Dosage Forms: Proprietary formulations of *Irvingia* are available in Europe and America mainly for the treatment of obesity. These are usually dried extracts of the seeds in capsules and tablets. The total seed powder is produced by Intercedd Health Products (Nigeria) in cubes for cooking as soup thickeners and for the management of diabetes. It is also a key ingredient in the African soup kitchen diet plan, which aims at simultaneously reducing obesity and other metabolic-syndrome-related diseases

such as diabetes, atherosclerosis, and hypertension. Other key ingredients in the all-soup-and-fruit juice plan are bitter leaf (*Vernonia amygdalina*), dawadawa (*Parkia biglobosa*), coco powder, guava, pumpkin leaves, pigeon pea, garden egg, *Moringa*, *Gnetum*, and *Xylopia aethiopica*. Local production of the dika wine is limited to parts of Western Cameroon and Eastern Nigeria.

Cacao: Cocoa

Overview

Cocoa is the product obtained from the "bean" of cacao tree (*Theobroma cacao*), which is cultivated in the equatorial regions of the continent and elsewhere. It is a delicate crop that requires a hot climate with high levels of precipitation to grow and produce optimal yields. The cocoa "bean" develops in large and often colorful pods that contain the bitter seeds used in the manufacture of cocoa and, subsequently, chocolate and other cocoa beverages. There are three main types of the cacao plant: *Criollo*, *Forastero*, and *Trinitario*. Each cultivar has distinguishable characteristics such as yield, susceptibility to diseases, resilience to climate variations, and taste and color of the finished product. Cocoa contains a mixture of polyphenols that are collectively called cocoa polyphenols (up to 10% w/w of dry bean) consisting mainly of catechins or flavan-3-ols (ca. 37%), anthocyanins (ca. 4%), and proanthocyanidins (ca. 58%). Cocoa polyphenols have demonstrated strong antioxidant properties as evidenced by the very high oxygen radical absorbance capacity (ORAC) value. Carbohydrates, proteins, vitamins, minerals, the alkaloid theobromine, and trace amount of caffeine and related methylxanthines have also been identified. Cocoa contains over 300 volatile compounds, including esters, hydrocarbons, lactones, monocarbonyls, pyrazines, and pyrroles. The pharmacological activities attributed to cocoa extracts and formulations include antioxidant, anti-inflammatory, cardioprotective, anticancerogenic, and neuroprotective effects.

Pharmacognostical Profile

Botanical Name: *Theobroma cacao* L.

Synonyms: There are more than 20 recognized synonyms for this plant, including the following: *Cacao minar* Gaertn.; *Cacao minus* Gaertn.; *Cacao sativa* Aubl.; *Cacao theobroma* Tussac; *Theobroma cacao* subsp. *cacao*; *Theobroma cacao* f. *leiocarpum* (Bernoulli) Ducke; *Theobroma cacao* subsp. *leiocarpum* (Bernoulli) Cuatrec; *Theobroma cacao* var. *leiocarpum* (Bernoulli) Cif.; *Theobroma cacao* subsp. *pentagona* (Bernoulli) León; *Theobroma cacao* subsp. *sativa* (Aubl.) León; *Theobroma integerrima* Stokes; *Theobroma kalagua* De Wild.; *Theobroma leiocarpum* Bernoulli; *Theobroma pentagonum* Bernoulli; *Theobroma saltzmanniana* Bernoulli; *Theobroma sapidum* Pittier; *Theobroma sativa* (Aubl.) Lign. & Le Bey; *Theobroma sativa* var. *leucosperma* A. Chev.; *Theobroma sativa* var. *melanosperma* A. Chev.; *Theobroma sativum* (Aubl.) Lign. & Bey.

Family: Malvaceae (formerly Sterculiaceae)

Common Names: Cacao tree, cocoa bean, coco

Description: Cacao is a medium-size evergreen tree that grows up to 15 m tall, but for ease of harvesting in commercial cultivation it is not allowed to grow taller than 6–8 m. Various cultivars of cacao are cultivated. It produces oblong or oval fruit, commonly called

a pod, 4–12 inches long, and green when immature, but may be yellow, red, purple, or green when ripe. Pods are produced throughout the year, but the main harvest usually begins at the end of the wet season and may extend for 3 months. Each tree produces 100–300 fruits a year. It is an indehiscent drupe called a pod or "cabosside." It can be spherical, cylindrical, pointed or blunt, smooth, or wrinkled. The pericarp has a thickness of 10–15 mm and can be of different colors depending on the ripeness and variety, turning from green to yellow, from red to orange. The fruit contains 20–60 reddish-brown beans 3/4 to 1/2 by 1/2 to 1 inch in size, usually arranged in five rows. Each cocoa bean consists of two cotyledons (nibs) and a small embryo, all enclosed in a skin (shell). The cotyledons contain two types of cells: storage or parenchyma cells, containing fat globules, protein, and starch granules, and pigmented cells, containing polyphenols and methylxanthines.



Inflorescence: The cacao tree flowers all year round; the flowers arise in groups directly from the old wood of the main stem or older branches at points that were originally leaf axils. Each flower has five prominent pink sepals, five smaller yellowish petals, each of which forms a pouch, an outer whorl of five staminodes, and an inner whorl of five double stamens, each stamen bearing up to four anthers. The staminodes are about as tall to twice as tall as the upright style and form a "fence" around the style. The stamens are curled so that the anthers develop inside the petal pouches. The ovary consists of five united carpels each having 4–12 locules, and one style that has several linear stigmatic lobes. The flower opens at about dawn, and the anthers dehisce just before sunrise. The stigma is usually pollinated 2–3 h later but is receptive from sunrise to sunset on the day of opening. The stigma is receptive to pollen along its whole length, and not merely at the apex as in most flowers. If the flower is not pollinated, it usually sheds the following day. The number of flowers is frequently many thousands times greater than the number of fruits. It takes 4–8 months for flowers to develop into fruit.

Habitat and Distribution: *Theobroma cacao* originated from the upper basin of the Amazon and its headwaters (in Peru, Ecuador, Colombia, and Brazil). In Africa, the main areas of cocoa production are in West Africa (Ghana, Nigeria, Cameroon, and Ivory Coast) and it appears that the Amelonado variety (from Bahia) and Trinitario were introduced during the nineteenth century and Forastero from the upper Amazon basin was introduced shortly after 1945. Cacao trees grow well as understory plants in humid forest ecosystems. They are cultivated between 18° north and 15° south, best at altitudes above 300 m above sea level but never at more than 1200 m. The light-sensitive plant prefers conditions

in which only 50%–75% of the sunlight filters through the foliage, a humid climate with annual precipitation of about 1500 mm, and temperature of about 23°C. The cacao tree is a delicate plant that needs to be sheltered from wind and therefore cultivated together with other more robust crops to provide shade.

Culinary (Food) Use: Cocoa is consumed as a beverage. It is used in making chocolate, ice creams, and other occasional foods.

Ethnomedicinal Uses: Cocoa butter is a useful vegetable fat used for cooking and preparing herbal remedies. The seeds have been used for skin applications, and in remedies for respiratory, nutritional, nervous, and metabolic system diseases. Various parts of the plant have been reported as diuretic, ecbolic, emmenagogue, and parasiticide, as well as for burns and wounds, cough, fever, listlessness, malaria, nephrosis, parturition, and rheumatism.

Constituents: The most notable active constituent from cacao is theobromine (3,7-dimethylxanthine), a compound similar to caffeine. The alkaloid is partially bound to tannins in cotyledon cells. During fermentation or roasting, however, the development of acetic acid permits the release of theobromine that migrates from cotyledons to shells. Theobromine yield in the cocoa shells is about 1.5% from where it can be extracted after processing for cocoa. It also contains a mixture of polyphenols that are collectively called cocoa polyphenols (up to 10%w/w of dry bean) consisting mainly of catechins or flavan-3-ols (ca. 37%), anthocyanins (ca. 4%), and proanthocyanidins (ca. 58%). Carbohydrates, protein, vitamins, minerals, and trace amounts of caffeine have also been identified. Cocoa contains over 300 volatile compounds, including esters, hydrocarbons, lactones, monocarbonyls, pyrazines, and pyrroles. The important flavor components are aliphatic esters, polyphenols, unsaturated aromatic carbonyls, pyrazines, diketopiperazines, and theobromine. Other constituents include tyramine, dopamine, salsolinol, trigonelline, nicotinic acid, free amino acids, and tannins. The husk contains a heat-resistant and light-resistant pigment that consists of polyflavone glucoside with a molecular weight of over 1500 that is highly stable at pH 3–11, and useful as a food colorant; cocoa butter contains mainly triglycerides of fatty acids that consist primarily of oleic, stearic, and palmitic acids. Over 73% of the glycerides are present as monounsaturated forms (oleopalmitostearin and oleodistearin), the remaining being mostly diunsaturated glycerides (palmitodiolein and stearodiolein), with lesser amounts of fully saturated and triunsaturated (triolein glycerides). Linoleic acid levels are up to 4.1%. Small amounts of sterols and methylsterols, mainly of β-sitosterol, stigmasterol, and campesterol, have been isolated from cocoa butter.[165] Cocoa beans are rich in proteins, which make up 10%–15% of the dry weight of cocoa seeds, the second most abundant constituent after cocoa fat. Proteins are the cocoa fraction that undergo the most intensive modification during fermentation, where microbiological and enzymatic reactions lead to extensive breakdown of cocoa seed proteins, yielding peptides and amino acids that are the important flavor precursors.[166]

Pharmacological Studies: Several pharmacological studies have been reported on the activities of cacao extracts, liqueurs, and chocolate. These include antioxidant, anti-inflammatory,[167] cardioprotective, anticancerogenic,[100] and neuroprotective effects.[168] It has been shown that health benefits of proanthocyanidins are related to their structures.[169] It was only in 1996 that Kondo et al.[170] carried out the first clinical study of chocolate. He showed that 35 g of delipidated cocoa decreased LDL oxidation between 2 and 4 h after ingestion. Since then, at least another 50 human studies involving the use of cocoa in different forms have been performed. A multitude of properties have been described. All of these may be summarized under five main headings: antioxidant, anti-inflammatory, atherosclerosis, cardiovascular protector, and antitumoral.[171] Following ingestion of cocoa polyphenols,

the flavanols first react with proline-rich proteins in the mouth to elicit an astringent response. Human studies have shown that flavanols and procyanidins are stable during gastric transit. It has been proposed that in the acidic environment of the gastric milieu, a significant proportion of flavanol oligomers are hydrolyzed into monomers and dimers, enhancing their absorption in the small intestine, but possibly modifying their biological activity.[172] Cocoa polyphenols have been shown to reduce blood pressure, improve insulin sensitivity, and induce vasodilation of the peripheral and cerebral vascular system, mainly by improving nitric oxide bioavailability in endothelial cells.[173]

Toxicity: Cocoa is well tolerated and no adverse effects have been observed even at very high doses or following chronic consumption. Some investigators[174] have raised the possible negative effects of procyanidins as antinutritional compounds due to their likely interactions with proteins, starch, essential amino acids, and carbohydrates, and inhibition of certain enzymes.[175] This binding depends on the degree of polymerization; the larger molecules (usually tannins) tend to bind more efficiently. However, at the dose present in cocoa, no adverse effect has been observed. Moreover, natural cocoa is a bitter-tasting substance and the overprocessed products available as chocolates are unlikely to contain much of the natural substance and probably many synthetic additives. The real production challenge is to have more authentic cocoa products made available.

Commerce and Agriculture: The annual cocoa consumption is estimated at about 6,000,000 tons in 2016. Europe is the largest cocoa-processing region, followed by the United States, and the Asia and Oceania region. Africa is involved mainly in the cultivation and sale of raw unprocessed cocoa beans. This is gradually changing as many processors are emerging in Africa, and in some countries, government policies favor the export of value-added semi-finished products rather than raw cocoa beans. The consumption also reflects the processing pattern with Europe as the largest cocoa consumer, accounting for 48% of the total world consumption of cocoa followed by the Americas at 33%. The world per capita consumption of cocoa has also seen a similar pattern of growth, rising from 0.54 kg in 2002 to 0.61 kg in 2010. This is likely to grow even stronger in the coming years as consumers, especially European and American chocolate aficionados, are asking for single-origin premium chocolate and "high cocoa content" products, with their own distinctive flavors. The health-promoting properties ascribed to chocolate are derived from the constituents in cocoa bean and manufacturers may be compelled to offer products that have high cocoa content with little or no added milk and sugars.

Cacao Varieties: There are three main types of cocoa: Criollo, Forastero, and Trinitario. Criollo is cultivated mainly in Venezuela, Central America, and Madagascar. It represents only about 5%–7% of total global production, with a low yield of only 20 beans per fruit, more vulnerability to diseases, and greater sensitivity to climate change than the other two cultivars. It has a rich, fruity, and smooth taste and yields a chocolate that has a reddish inside when broken. Forastero is the variety cultivated in Africa. It represents about 80% of the global production of cocoa. It is a high-yielding crop with each fruit producing between 40 and 50 beans. The variety has an acrid, bitter, and less aromatic flavor. The fracture surface of the chocolate from the Forastero bean is black. The Trinitario variety is a hybrid of the Criollo/Forastero cultivars. It retains the desirable properties of both constituent types, that is, it is high yielding, high in fat content, aromatic, and resistant to diseases. It represents about 15% of the world market and is cultivated in Madagascar, Venezuela, and the West Indies.

Cocoa Processing and Effect on Health Benefits of Cacao: The processing of cocoa involves very complex and specific steps. The characteristics of the finished products are determined by the nature and care taken in the processing, from the farm, through

the initial processing, to the production line. Harvesting, fermentation, and drying are carried out in the countries of origin. Local or regional variations in cocoa plant materials, fermentation procedures, and drying processes lead to a traded good typical of the country of origin; therefore, the composition of the fermented cocoa beans, which is one of the most important factors influencing taste and flavor of the cocoa products, depends not only on the cocoa variety but also on the geographic origin. The other steps, sorting, roasting, blending, crushing, and grinding, as well as pressing, conching, and tempering, are undertaken in the transformation countries. Cocoa undergoes technological transformations that affect the integrity of the chemical composition of the finished products. For example, during the initial fermentation of cocoa beans, there is a loss of most of the pulp around the beans because the pulp substrates are broken down through microbial action and some biochemical changes occur inside the cocoa beans that contribute to a reduction of their bitterness and astringency and improve their color and flavor. In this process, yeasts proliferate and convert sugars to alcohol; then the development of lactic acid bacteria occurs, which contributes to sugar breakdown producing lactic acid. After the pulp has run off, the conditions become more aerobic, and the presence of oxygen allows acetic acid bacteria to take over from the yeasts and convert alcohol to acetic acid. These acids derived from the pulp sugars penetrate the beans, lower the internal pH, and cause a breakdown of the polyphenols. The lipid membranes of the vacuoles of the cell, and the cell contents become mixed, allowing various enzymatic reactions to take place. One of the most important consequences is the oxidation of polyphenols and their conversion to insoluble forms due to the reactions with proteins; these reactions are responsible not only for the removal of the bitter taste from the beans but also for the strong reduction of total polyphenol content, thus affecting the antioxidant and health properties of cocoa.

These processes were accompanied by a number of other technological advances in the nineteenth century that helped change cocoa products from a bitter drink to the modern beverages and chocolates that are enjoyed by millions. Initially, the research on chocolate was aimed at understanding the potential harm, including tachycardia, but over the last two decades, this has changed dramatically with the investigation revealing some potential health benefits. The food industry has ceased the initiative to encourage work on the potential benefits of chocolate, without as much interest or funding for other cocoa products. A major property of cocoa and chocolate is that they are rich sources of polyphenolic compounds, which are stable over time. Chocolate has been shown to maintain its polyphenol content 2 years after manufacture, with low levels of contaminants and bacteria growth, characteristics not seen in fruits and vegetables, while other polyphenol-containing beverages (e.g., teas) appear to be less stable, with a shorter shelf life. The seemingly better bioavailability of polyphenols found in cocoa and chocolate has not been observed in other beverages.

The formulation of chocolate varies enormously, cocoa and cocoa butter usually have added sugar (typically sucrose) and, potentially, milk and/or other emulsifiers (typically soy lecithin). Most of the constituents and processes are proprietary and some formulations have added vegetable fats, such as palm oil, sal, shea, kokum gurgi, mango kernels, and copra oil. Cocoa powder has caloric value of about 310 kcal per 100 g (1300 kJ), 22 g of fat of which 13 g is saturated, and only a trace amount of sugar. However, cocoa consumed as chocolate or cocoa beverages contains added sugar and fat (often from added dairy fat), which can dramatically alter the nutritional composition. Although cocoa powder is a functional food with so many health benefits, however, by composition and definition, chocolate may not qualify as a functional food with a health claim simply because of its high content of added fat and sugar.

Calabash Nutmeg

Overview

Calabash nutmeg is a popular spice in Africa used for the preparation of soups, yam porridge, and convalescent meals. The plant contains volatile oils, alkaloids belonging to the benzyltetrahydroisoquinoline group, prenylated indoles, diterpenes, and sesquiterpenes. It has antimicrobial, anti-inflammatory, and antispasmolytic activities.

Pharmacognostical Profile

Botanical Name: *Monodora myristica* (Gaertn.) Dunal

Synonyms: *Monodora borealis* Scott-Elliot.; *Monodora claessensii* De Wild.; *Annona myristica* Gaertn.

Family: Annonaceae

Common Name: Calabash nutmeg

African Names: Hausa: gujiya'dan miwa; Igbo: ehuru, efuru; Yoruba: abo lakoshe, arigho, eyinaghose



Description: An ornamental tree of up to 30 m high, with dense foliage and a spreading crown. The stem is fluted, the bark fissured geometrically, the outer bark is thin and dark brown, and the inner bark is light brown above and pale cream beneath. The sapwood is soft, white, slowly turning pinkish after slashing. The stem is aromatic. The leaves are elliptic, sometimes becoming wider at the apex, about 14–16 cm long and 5–14 cm broad, arranged alternately. The apex is shortly pointed, and the base rounded or slightly caudate. The leaves display up to 20 pairs of prominent lateral veins, and parallel secondary nerves. It flowers from September to April, at the time of the appearance of new leaves. The fruits are large, fragrant, and pendant, hanging on very long stalks with a crinkly bract about 2.5 cm long near the end of the stalk. Sepals are about 4 cm long, spotted with red, and with wavy edges and crisped. There are six petals; the outer ones, about 10 cm long, bright yellow in color and with dark red marks on the edge and toward the end. The inner petals are subtriangular, dull cream-yellow, with red spots on the inner side.

The fruits are produced in April–September, about 15 cm in diameter, green, round, and woody, suspended in a long stalk. The pulp is white and contains numerous seeds about 2.5 cm long.

Culinary (Food) Use: It is used as a spice and condiment for cooking soups and stews.

Ethnomedicinal Uses: The seeds yield a colorless, volatile oil with a pleasant taste and odor, and are used as condiments for soup and added into snuffs as a flavoring agent. The seeds are also used to treat migraine (external application on the forehead), as a stomachic, and mixed with palm oil as stimulant. A pomade is produced the pulverized seeds fried in oil and the powder is used to treat guinea worms and other sores. A related species *M. tenuifolia* is used as an anthelmintic and in Yoruba traditional medicine for the treatment of toothache.

Constituents: The plant contains volatile oils, alkaloids belonging to benzyltetrahydroisoquinoline group, prenylated indoles, diterpenes, and sesquiterpenes. A related species *Monodora brevipes* yielded the proaporphine alkaloids, crotsparine and stepharine, 3-formylindole, the sesquiterpene (–)-α-cadinol and the monoterpene lα,6β-dihydroxy-4α-*p*-menth-2-ene, and clerodane diterpenes.[176]

Pharmacological Studies: The essential oils and extracts of *M. myristica* are known to possess antimicrobial properties. The antibacterial and antifungal activities have been evaluated against some microorganisms.[177] In the *in vitro* assay against *Mycobacterium tuberculosis*, methanolic extract of the seeds showed both mycobacteristatic (IC_{50} = 512 μg/mL) and mycobactericidal (IC_{50} = 1024 μg/mL) activities on two strains of the organism tested.[178]

Cashew

Overview

Cashew is a versatile tree nut. It is valued for its edible nuts, which is a favorite snack worldwide. The main products from cashew traded on the global market are raw cashew nuts (RCNs), cashew kernels, and cashew nut shell liquid (CNSL). The leaves are rich in flavonoids and other polyphenols. The kernels contain a unique combination of fats, proteins, carbohydrates, minerals, and vitamins. The nut contains 47% fat, but 82% of this fat is unsaturated fatty acids, and thus can be considered not cholesterol enhancing. The unsaturated fat content not only eliminates the possibility of cholesterol enhancement but also balances or reduces total cholesterol in blood. The nut contains 21% protein and 22% carbohydrate and the right combination of amino acids, minerals, and vitamins. Nutritionally speaking, cashew can be considered on par with milk, meat, and eggs. Since the carbohydrate content in the nut is low, only 1% of soluble sugar, the sweet taste comes without excess calorie intake from sugary substances. It is a healthy nut recommended for diabetics and people at risk of cardiovascular diseases.

Pharmacognostical Profile

Botanical Name: *Anacardium occidentale* L.

Synonyms: *Acajuba occidentalis* Gaertn.; *Cassuvium pomiferum* Lam.; *Anacardium microcarpum* Ducke.

Family: Anacardiaceae

Common Name: Cashew

African Names: Krio: kushu; Mende: kusui; Temme: e-lil-e-potho; Yoruba: kaju; Hausa: kadinnia; Kanuri (Hausa): kanju; Igbo: kashu

Description: The cashew is a small tree, with leaves that are alternate, simple, entire, obtuse, and borne on short leaf stalks. The flowers are abundant, small, and fragrant, and produced in terminal, loose panicles. The enlarged juicy peduncle that bears the nut is known as the "cashew apple." When ripe, it is of a golden-yellow color, obovate in shape, has a pleasant, acid flavor, and is somewhat astringent. The cashew nut hangs from the end of the cashew apple, and is kidney-shaped and about 2.5 cm long. It consists of an edible kernel, surrounded by two shells. The outer shell is smooth and of a bright brown color. Between the two shells, there is a very caustic oily substance. The cashew kernel is considered to be of high nutritive quality, and is covered with a thin reddish brown skin or testa.[179]



Habitat and Distribution: The cashew tree was originally native to Brazil and was later introduced by the Portuguese to Mozambique and then India in the sixteenth century, as a means of controlling coastal erosion. It was not until the nineteenth century that plantations were developed, and the tree then spread to a number of countries in Africa, Asia, and Latin America. The cashew is now distributed throughout the tropics and in parts of the warm subtropics. Cashew processing, using manual techniques, began in India in the first half of the twentieth century, when cashews were exported to the wealthy Western markets, particularly the United States.

Ethnomedicinal Uses: All parts of the tree are used in traditional medicine. Cashew leaves are used extensively for the treatment of fevers, skin disease, diabetes, and hypertension. The fresh juice from the fruit is effective for the treatment of syphilis, as an antiscorbutic, astringent, and diuretic, and for the treatment of cholera and kidney disease. Root infusion is an excellent purgative. The stem bark is astringent, counterirritant, rubefacient, and vesicant, and used for ulcers. Cashew nut shell oil is antihypertensive and purgative; it is used for blood sugar problems, kidney diseases, cholera, cracks on the soles of the feet, hookworm, corns, and warts. The kernel is a demulcent and an emollient and is used for diarrhea. The resinous juice of seeds is used for mental derangement, heart palpitation, and rheumatism. A gum that exudes from the trunk repels insects. An extract of the pericarp and nut is used to treat wood to give complete protection against beetles. Cashew syrup is a good remedy for coughs and colds. Cashew apple juice is said to be effective for the treatment of syphilis.

Constituents: Cashew elaborates a complex mixture of compounds in different parts of the plant.[180] The kernel testa (skin) is reported to contain huge amounts of tannin, and the tannin extracted from cashew kernel testa is used in the leather industry. The juice of the cashew apple is rich in riboflavin (vitamin B2), ascorbic acid (vitamin C), and calcium. The nut contains 47% fat, but ca. 82% of this fat is unsaturated fatty acids (60%–74% oleic acid and 20%–8% linoleic acid), which not only eliminates the possibility of cholesterol enhancement but also balances or reduces total cholesterol in blood. The nut contains 21% proteins and 22% carbohydrates and the right combination of amino acids, minerals, and vitamins.

The nutrient composition of cashew fruit "apple" is shown in Table 10.1.

CNSL contains 90% anacardic acid ($C_{22}H_{32}O_3$) and 10% cardol ($C_{32}H_{27}O_4$). It also yields glycerides, linoleic, palmitic, stearic, and lignoceric acids, and sitosterol. Other constituents include anarcardol, cardanol, quercetin, and kaempferol glycosides. The presence of the phenolic lipids related to anacardic acid in cashew is of immense industrial and therapeutic importance. The testa contains α-catechin, β-sitosterol, and 1-epicatechin as well as proanthocyanadin, leucocyanadin, and leucopelargonidin. The dark color of the nut is due to an iron-polyphenol complex. The oil content of the shell ranged from 16.6% to 32.9% and that of the kernel from 34.5% to 46.8%. Reducing sugars ranged from 0.9% to 3.2%, nonreducing sugars from 1.3% to 5.8%, total sugars from 2.4% to 8.7%, and starch from 4.7% to 11.2%. Gum exudates contain arabinose, galactose, rhamnose, and xylose.

Pharmacological Studies: The pharmacological properties of cashew are usually classified according to the plant part of interest. Leaves derive their activity due to the presence of flavonoid glycosides. The leaves have been shown to be effective antimicrobial agents.[181] The so-called cashew apple contains nutrients that play health restorative roles. The most active components of cashew are in the oils obtained from the shell. Anarcadic acid has been shown to possess broad-spectrum activity against various bacteria, fungi, and algae.[182] It has proved very useful in treating tooth abscesses. Perhaps of greater importance is its potentiating effect on antibiotics used for the treatment of drug-resistant Gram-positive and Gram-negative bacteria.[183] It has also been shown to possess insecticidal and molluscicidal activities, as well as enzyme inhibition with potential application in certain cancers.[184]

TABLE 10.1

Composition of Cashew Apples

Moisture	86.1 (g/100 g)
Proteins	0.8 (g/100 g)
Fat	0.2 (g/100 g)
Carbohydrate	12.6 (g/100 g)
Fiber	0.6 (g/100 g)
Ash	0.3 (g/100 g)
Ca	0.2 (mg/100 g)
P	19.0 (mg/100 g)
Fe	0.4 (mg/100 g)
Vitamin B1	0.2 (thiamine mg/100 g)
Vitamin B2	0.2 (riboflavin mg/100 g)
Niacin	0.5 (mg/100 g)
Vitamin C	200 (mg/100 g)

Toxicity: Some people are allergic to raw cashew nuts and cardol and anacardic acid in CNSL. Proteins found in the kernel have been identified as contributing to the allergic reaction to cashew. Cooking often does not remove or change these proteins. These allergic reactions can be life threatening or even fatal; prompt medical attention is necessary. Care must be taken before cashew products are taken by sensitive individuals. Dermatitis among cashew nut workers has been reported in many countries. During processing, care should be taken to ensure that CNSL do not contaminate the kernels.

Commerce: Cashew is cultivated for the nuts. Botanically, the nut is the fruit; the cashew apple is the swollen, fleshy fruit stalk. The seed kernels are extracted by shelling the roasted nuts. In production areas, cashew serves as food. Elsewhere, it forms a delicacy. The nut contains a high-quality oil; the cake remaining after extraction serves as animal feed.

Agriculture: Nigeria was the world's largest producer of cashew nuts with shell in 2010. Most of the cashew nuts produced in Africa are still exported as raw nuts. Propagation is generally by seeds, but may be vegetative from grafting, air-layering, or inarching. Cashew germinates slowly and poorly; several nuts are usually planted in a hole and thinned later. Planting is better done *in situ* as cashew seedlings do not transplant easily. The recommended spacing is 10×10 m, thinned to 20×20 m after about 10 years, with maximum planting of 250 trees/ha. Once established, the field needs little care. Intercropping is common and may be done the first few years, with cotton, peanut, or yams. Fruits are produced after 3 years, during which lower branches and suckers are removed. Full production is attained by the 10th year and the plant continues to bear fruits until about 30 years old. In dry areas, like Tanzania, flowering occurs in the dry season, and fruits mature in 2–3 months. Flowers and fruits in various degrees of development are often present in the same panicle. From the flowering stage to ripe fruit requires about 3 months. Mature fruit falls to the ground where the "apple" dries away. In wet weather, they are gathered each day and dried for 1–3 days. Mechanical means for shelling have been unsuccessful, so hand labor is required. Cashews are usually roasted in the shell (to make it brittle and the oil-less blistering), cracked, and nuts removed and vacuum packed.[185]

Value-Added Products from Cashew

Cashew kernels are used worldwide as a snack but most of the exports from Africa are raw cashew kernels sent to India and Europe for processing. Various diversified products can be obtained from the raw cashew kernels with minimum product development. Value addition through minimum processing can substantially enhance the economy of cashew production as explained below.

1. *Cashew kernel flour*: The low-grade kernels, which can neither be exported nor sold in the domestic market, are made into cashew flour, which is highly proteinaceous and is easily digested. It is an excellent supplement to usual wheat flour.
2. *Cashew kernel oil ("Caribbean oil")*: The kernel contains 35%–40% oil that can be used as a substitute for imported olive oil. As in the case of cashew kernel flour, lower-grade kernels are also used to extract kernel oil, which is a highly nutritious edible oil, and in terms of quality, compares quite well with the healthy and nutritious olive oil.
3. *Cashew kernel butter*: The residue of kernel after oil extraction is used to produce cashew kernel butter, which is similar to peanut butter. The oil-expelled kernel

can also be processed into cashew nut cake, which is an excellent animal feed, especially for dairy cows.

4. *Coated cashew kernels*: Sugar-, honey-, and salt-coated cashew "baby bits" are available in the market. Baby bits are the lowest-grade kernels that are commercially marketed.
5. *Cashew kernel milk*: Sweetened and flavored cashew milk can be prepared from cashew baby bits.
6. *Cashew spread*: Cashew spread can be prepared from baby bits.

Clove

Overview

The clove tree, *Syzygium aromaticum*, is an evergreen tree that grows up to 8–12 m tall, with large leaves and sanguine flowers grouped in terminal clusters. The flower buds initially have a pale hue, gradually turn green, and then transition to a bright red when ready for harvest. The aromatic flower buds are the part used in medicine and the article of trade. Clove yields volatile oil, which consists of up to 90% eugenol. The other constituents are gallotanic acid, β-caryophyllin, methyl salicylate, benzaldehyde, and sesquiterpenes α-cubebene, cardenes, and α-copene. Two ellagitannins, named syzyginins A and B, occur in the leaves. Clove is incorporated in many proprietary products for toothache, oral hygiene, and as a general anodyne. It has been shown to be antidiabetic, anti-inflammatory, and insect repellent. Some studies also suggest that it has fever reduction activity, and the ability to prevent premature ejaculation.

Pharmacognostical Profile

Botanical Name: *Syzygium aromaticum* (L.) Merr. et Perry

Synonyms: *Caryophyllus aromaticus* L.; *Eugenia aromatica* (L.) Baill.; *Eugenia caryophyllata* Thumb.; *Jambosa caryophyllus* (spr.) Neid.; *Eugenia caryophyllus* Spreng.

Family: Myrtaceae

Common Names: Clove (E). Clou de girofle. Giroflier (f).

African Names: Arabic: karanfal; Bambara: benefundi; Hausa: kanumfari, karanho, kade; Igbo: osaragbogo-eze; Swahili: karafwu; Yoruba: konofuru

Description: Cloves are small evergreen trees that are 10–15 m tall. The leaves are opposite, petiolated lanceolate with translucid aromatic glands. They have a pungent odor and are pink when young. The inflorescence, which occurs as racemose panicles and bears buds that take on the form of nails before blossoming, constitutes the spice. The flowers are red and have four concave, overlapping petals that drop as soon as the flower opens. There are numerous stamens and four calyx teeth. The fruit is a dark and red, fleshy drupe. Clove buds have a strong aromatic, characteristic odor, and a pungent and spicy taste, followed by a slight aromatic, characteristic odor, and a pungent and spicy taste, followed by a slight numbness. Clove readily exudes oil when pressed or scratched by the fingernail.



Habitat and Distribution: The plant originated in Indonesia but is now grown in some parts of Africa, especially in the islands of Indian Ocean (the Comoro archipelago, Madagascar, Reunion Island, and Zanzibar).

Culinary (Food) Use: Cloves are used as spice, to flavor meats, curries, and marinades. It is also used as an added flavor to fruit juices and hot beverages.

Ethnomedicinal Uses: Clove and clove oil are used as anodynes for toothache and mouth infections. The plant is used as an antiseptic dressing for wounds. It has also been dispensed for coughs, stomachache, and as a stimulant and carminative. Other *Syzygium* species, especially *S. guineense* and *S. cordatum*, are also used as remedies for various diseases. *S. guineense* is used in West Africa and by the Swahili as a remedy for dysentery. In Central Africa, a decoction of the bark is used in the treatment of diarrhea. The Bemba use a decoction of the leaf of *S. cordatum* as a remedy for stomachache and diarrhea, and they apply a poultice of the pounded leaf, bark, and root to the breast of the nursing mother to increase the flow of milk. The Zulu use the plant and a related species *S. gerrarde* as a tuberculosis remedy and emetic. The powdered bark is sprinkled on the water as an effective fish poison but it is not toxic to big fish and warm-blooded animals.

Constituents: It yields 15%–20% of volatile oil, which consists of up to 90% eugenol and about 13% gallotanic acid and β-caryophyllin, methyl salicylate, benzaldehyde, and sesquiterpenes α-cubebene, cardenes, and α-copene.[186] Two ellagitannins, named syzyginins A and B, were isolated from the leaves.[187] The plant also contains the sterols, sitosterol, campesterol, and sigmasterol, as well as the flavonoids kaempferol and rhamnetin.

Pharmacological Studies: Clove has been shown to possess antiseptic, antispasmodic, antihistamine, and anthelminthic properties.[188] Eugenol is widely used in dentistry to deaden the pain of toothache and to probe tooth decay. The oil and aqueous extracts potentiate the activity of trypsin.[1] It possesses antioxidant[189] and antimicrobial activities.

It has been used in combination with *Lavandula angustifolia* and *Geranium robertianum* for the treatment of acute external otitis (AEO). The herbal combination eye drop (Lamigex) preparation was compared with ciprofloxacin 0.3% drop in the alleviation of AEO symptoms. All assessed symptoms (tenderness, itching, erythema, edema, and discharge) were equally improved in the ciprofloxacin and Lamigex groups by the end of trial ($P > 0.05$). There were remarkable reductions in the visual analog scale score by the end of trial in both groups ($P < 0.001$). However, the rate of pain improvement was not found to be

significantly different between the groups, either at the 3rd or 7th day of trial ($P > 0.05$). The numbers of positive cultures for all tested microorganisms were clearly reduced by the end of the trial in both groups but were not significantly different between the groups ($P > 0.05$).[190]

It has shown activity against *Trypanosoma cruzi*,[191] *Lymnaea acuminate*,[192] and xerophilic aflatoxigenic fungi associated with marketed tea.[193] The hexane extract has a biphasic action on testicular function[194]: a low dose (15 mg) of the extract for 35 days increased the activities of Δ^5 3 β-HSD and 17 β-HSD, and serum level of testosterone; the higher doses (30 and 60 mg) of the extract inhibited these parameters and induced nonuniform degenerative changes in the seminiferous tubules associated with decrease in daily sperm production and depletion of 1C (round and elongated spermatids) population. These results indicate that caution is required in the use of the flower bud of *Syzygium aromaticum* as an aphrodisiac in indigenous systems of medicine or as dietary supplement.

The probable biochemical mechanism of the antidiabetic action of clove has been outlined by Adefegha and Oboh.[195] It was found that the phenolics-rich extracts inhibited α-amylase and α-glucosidase in a dose-dependent manner. However, the α-glucosidase inhibitory activity of the extracts were significantly ($P < 0.05$) higher than their α-amylase inhibitory activity. The free phenolics (31.67 mg/g) and flavonoid (17.28 mg/g) contents were significantly ($P < 0.05$) higher than bound phenolic (23.52 mg/g) and flavonoid (13.70 mg/g) contents. The extracts also exhibited high antioxidant activities as typified by their high reducing power, 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2-azinobis-3-ethylbenzo-thiazoline-6-sulfonate (ABTS) radical-scavenging abilities, as well as inhibition of Fe^{2+}-induced lipid peroxidation in rat pancreas *in vitro.* It was suggested that these activities could explain the biochemical rationale by which clove elicits therapeutic effect on type 2 diabetes.

Coconut

Overview

All parts of the coconut tree are economically useful. The most valuable part, however, is the fruit that encloses a seed, the coconut that is spherical in shape with a hard shell that encloses an oil-rich albumen and the coconut water. A ripe fruit can be recognized by shaking the water inside the nut. The dried endocarp is known as copra and yields coconut oil, which is valued as an emollient for ice creams and similar foods and used as an ingredient in remedies for skin infections. The oil obtained from the fresh endocarp (either raw or fermented), called virgin coconut oil (VCO), has been shown to have various therapeutic applications, including antioxidant, antidiabetic, and immunomodulatory activity and for the treatment of peptic and duodenal ulcers. Coconut oil is rich in lauric acid (44%) as well as capric acid, acrylic acid, palmitic acid, stearic acid, arachidic acid, oleic acid, and linoleic acid. It is a rare source of galactose (found in milk) and also contains sucrose, raffinose, pentose, fructose, glucose, dextrin, and starch. VCO contains mainly medium- and short-chain fatty acids, polyphenols, derivatives of fatty acid (betaines, ethanolamide, ethoxylates, fatty esters, fatty polysorbates, monoglycerides, and polyol esters) fatty chlorides, fatty alcohol sulfate and fatty alcohol ether sulfate, vitamins, and minerals.

Pharmacognostical Profile

Botanical Name: *Cocos nucifera* L.

Synonyms: *Coccus mammilaris* Blanco.; *Calappa nucifera* (L.) Kuntze.; *Coco sindica* Royle.; *Cocos nana* Griff.; *Palma cocos* Mill.

Family: Arecaceae

Common Name: Coconut

African Names: Arab: gos el-hind; Bambara: coco; Hausa: kwarkwar-attagara; Igbo: akibeke; Swahili: nazi (mbata = copra); Yoruba: igi agbon

Description: The coconut tree is a monoecious palm tree of 200 m in height. Its trunk is striated or curved but unbranched, with marked foliar scars, and topped by a crown of pinnet leaves, ranging from 3 to 5 m in length and about 30 in number. There is a central bud, which if cut off leads to the death of the whole tree. The inflorescence is surrounded by spathes; the male and female flowers are produced separately in the leaf axils, usually succeeding each other on a long stalk. It produces many fruits, but only a few reach maturity, ca. 70% being shed during the year-long development. The fruit encloses a seed, the coconut that is spherical in shape with a hard shell that encloses an oil-rich albumen and the coconut milk. A ripe fruit can be recognized by shaking the milk inside the nut.



Habitat and Distribution: Coconut palms grow best in pure sand, usually in coastal regions. They tolerate the high salt concentrations of ocean beaches, but need humid climate and plenty of sunlight. The plant is a major crop in Ghana, Ivory Coast, Kenya, Nigeria, Mozambique, Togo, Somalia, Seychelles, Malagasy Republic, and Tanzania.

Culinary (Food) Use: Delicious fruits, part of daily diet in many parts of the world. The "water" makes a refreshing drink, the oil is used in many dishes, and the endosperm is eaten as snacks.

Ethnomedicinal Uses: All parts of the plant are useful in Africa. The oil obtained from the dried endocarp is used in cosmetics and for food, coir fiber is obtained by soaking the outside husk in salt for 6–12 months, the midribs of the leaves are made into brooms, and

the leaves and trunks are used in erecting and roofing temporary buildings. The palm fronds are used for making mats, baskets, and art works. Coconut (water) milk is a refreshing drink, and it is mainly used as a poison antidote. It is not usually recommended for those with cardiac problems. The oil from the nuts is valued as an emollient and used as an ingredient in remedies for skin infections. Perhaps of greatest therapeutic application is the oil from the fresh endocarp, called VCO.

Constituents: The African pharmacopeia indicated that dry copra (coconut meat) contains 6.3% protein, 57.3% fat (oil), 38% carbohydrate, and 2% minerals. It also contains 14.33% sucrose, 2.42% raffinose, 2.42% galactose, 2.40% pentose, 1.20% fructose, 1.19% glucose, 0.58% dextrin, and 0.87% starch. The fatty acid profile of coconut oil is as follows (percentage in parentheses): capric acid (0.2–0.5), acrylic acid (4–9.5), caprylic acid (4.5–9.7), lauric acid (44.1–51), myristic acid (13.1–18.5), palmitic acid (7.5–10.5), stearic acid (1.0–3.2), arachidic acid (0.2–1.5), oleic acid (5.0–8.2), and linoleic acid (1.0–2.6).

Pharmacological Studies: Phenols obtained from the nutshell possess significant antifungal activity at 100 μg/mL against three *Microspermum* and four *Trichophyton* species, as well as antitubercular activity. Fresh coconut milk has been found to interfere with the absorption of some orally administered drugs and to exhibit a moderate antihistamine effect. The most abundant fatty acid in coconut, lauric acid, possesses several biological activities. Lauric acid is known to have antiviral, antibacterial, and antiprotozoal qualities. It is converted to the monoglyceride monolaurin in the human or animal body. Monolaurin itself is antiviral, antibacterial, and antiprotozoal.

Available publications indicate that monolaurin is capable of destroying lipid-coated viruses such as HIV, herpes, cytomegalovirus, influenza, various pathological bacteria, including *Listeria monocytogenes* and *Helicobactor pylori*, and protozoa such as *Giardia lamblia* and *Plasmodium falciparum*. It is believed that the compound is synthesized in babies from the lauric acid of mother's milk.[196] Caprylic acid, another fatty acid found in coconut, also has antimicrobial activities. Reports also suggest that coconut oil is useful as an antioxidant, antihypertensive, and antidiabetic functional food. The fatty acids can be used for the production of biodiesel through an enzymatic conversion process.[197]

There is no unanimity regarding the health benefits of coconut oil.[198] It has been suggested that the initial negative recommendation on the nutritional value of coconut oil was based on faulty scientific evidence and propaganda to promote the use of nontropical oils from industrialized countries such as corn oil and cottonseed oil. Nutritional experts in the United States and Canada still caution against the use of coconut oil because of the abundance of saturated fatty acids in the oil and the potential risk of high cholesterol and its health risks.[199]

Virgin Coconut Oil: VCO is unprocessed oil obtained from fresh coconut endocarp. It contains medium-chain fatty acids that are assimilated more easily by the body than the long-chain fatty acids found in many other cooking oils. It has become a major dietary supplement with many beneficial properties. VCO has the following constituents:

- Lauric acid, medium-chain triglycerides, and other saturated fatty acids, including capric acid, caprylic acid, myristic acid, and palmitic acid
- Monounsaturated fatty acids: oleic acid
- Polyunsaturated fatty acids: linoleic acid
- Polyphenols, gallic acid, and phenolic acids
- Derivatives of fatty acids: betaines, ethanolamide, ethoxylates, fatty esters, fatty polysorbates, monoglycerides, and polyol esters

- Fatty chlorides, fatty alcohol sulfate, and fatty alcohol ether sulfate, all of which are derivatives of fatty alcohols
- Vitamin and minerals: vitamin E, vitamin K, and iron

Advocates of the VCO as a dietary supplement claim the following health benefits: immune modulation, diabetes, high blood pressure, cancer, hair care, skin care, stress relief, maintaining cholesterol levels, weight loss, bone strength, proper digestion and metabolism, heart diseases, dental care, HIV, and relief from kidney problems. It is believed that these health benefits of VCO can be attributed to the presence of the medium-chain fatty acids and phenolic compounds, with their known properties such as antimicrobial, antioxidant, antifungal, antibacterial, and anti-inflammatory properties.

Tender Coconut Water (TCW): The TCW, the liquid endosperm, is an excellent natural refreshing drink, with a caloric value of 17.4/100 g. Coconut water contains vitamin B, namely, nicotinic acid B3 (0.64 μg/mL), pantothenic acid B5 (0.52 μg/mL), biotin (0.02 μg/mL), riboflavin B2 (<0.01 μg/mL), folic acid (0.003 μg/mL), trace amounts of thiamine B1 and pyridoxine B6. Coconut water also contains sugars, sugar alcohols, vitamin C, folic acid, free amino acids, phytohormones (auxin, 1,3-diphenylurea, and cytokinin), enzymes (acid phosphatase, catalase, dehydrogenase, diastase, peroxidase, and RNA polymerases), and growth-promoting factors.[200]

Coffee

Overview

Coffee consists of the bean of the coffee plant, *Coffea arabica* (and the closely related *C. robusta*), believed to originate from the Kaffa province of Ethiopia, where the species grows wild till this day. Coffee is one of the world's most widely consumed beverages and a major cash crop. Although the coffee beans are seeds, they are referred to as "beans" because of their resemblance to true beans. The bean occurs in the pit inside the red or purple fruit, often referred to as a cherry or stone fruit. The coffee berries usually contain two stones with their flat sides together but sometimes only a single seed is found inside a fruit, referred to as a "peaberry." Coffee used in beverages are usually processed by wet or dry methods for removing the outer pulp and mucilage, and have an intact wax layer on the outer surface, then roasted. The unroasted mature or immature coffee beans, referred to as "green coffee bean," are used as health foods and nutritional supplements, and have been clinically studied for the chlorogenic acid content and for possible use for the lipolytic and weight loss properties. The mature fruits are brown to yellow or reddish in color, and typically weigh 300–330 mg per dried coffee bean. The two most economically important varieties of coffee plant are the *C. arabica*, which accounts for about 80% of worldwide coffee production and *C. robusta* about 20%. Caffeine content varies enormously with Arabica containing 0.8%–1.4% caffeine and Robusta beans yielding 1.7%–4% caffeine. Coffee contains many nonvolatile nitrogenous compounds (including alkaloids, trigonelline, proteins, and free amino acids) and carbohydrates, which are important for its biological action. The lipids found in green coffee include linoleic acid, palmitic acid, oleic acid, stearic acid, arachidic acid, diterpenes, triglycerides, unsaturated long-chain fatty acids, esters, and amides. The total content of lipids in dried green coffee

is between 11.7 and 14 g/100 g. The diterpenes found in green coffee include cafestol, kahweol, 16-*O*-methylcafestol, cafestal, and kahweal. Some of these diterpenes and other coffee constituents have been shown in *in vitro* experiments to protect liver tissue against chemical oxidation. Green coffee contains volatile compounds, including short-chain fatty acids, aldehydes, and nitrogen-containing aromatic molecules, such as derivatives of pyrazines. Roasting generates more volatile compounds, some of which produce the characteristic pleasant coffee aroma. Coffee contains an abundance of polyphenols and phenolic acids, including chlorogenic acids, caffeoylquinic acids, feruloylquinic acids, dicaffeoylquinic acids, *p*-coumaroylquinic acids, caffeic acid, ferulic acid, and their derivatives. Much of the focus on coffee as a dietary supplement is on "green coffee" and products derived from it that are devoid of caffeine. Caffeine removal or "decaffeination" is done when the fruits are still green. There are many methods to remove caffeine from coffee, but all involve either soaking the green seeds in hot water (often called the "Swiss water process") or steaming them, and then using a solvent to dissolve caffeine-containing oils. The coffee beverage manufacturer and marketer Starbucks has successfully produced "Green Bean Refreshers" that primarily isolates the caffeine from the green beans, without actually using steeped liquid from the beans. Other procedures that aim at reducing the caffeine content and producing the so-called green bean "extract" have been reported by consumers, which involves steeping green coffee beans in hot water. Often, the recommended times of steeping (20 min to 1 h) will extract too much caffeine to provide a pleasant taste. A steeping time of 12 min or under provides a more palatable liquid that can be used as a base for a drink containing more of the nutrients and less caffeine than using just isolated caffeine extract. The alkaline stock base that results can be paired with acidic or fruity extracts, with or without sweetener, to mask the vegetable-like taste of the extract. The most well-known property of coffee is the psychoactive activity of caffeine, an adenosine antagonist that is known for its stimulant effects. Coffee also contains the monoamine oxidase inhibitors β-carboline and harmane, which may contribute to its psychoactivity. Other properties of coffee include the antioxidant activity of the polyphenols, antiproliferation effect, positive effects on mental health, and protective role against cardiovascular diseases. Meta-analyses have suggested that increased coffee consumption is associated with a reduced risk of prostate cancer, including deadlier forms of high-grade prostate cancer. Consuming coffee reduces the risk of skin cancer. Coffee extract and its constituents exhibit antioxidant and anti-inflammatory properties. Coffee extract also diminishes UVB-irradiation-induced photoaging by modulating the MAPK/MMP/type I procollagen pathway. It has been reported that topical application and oral administration of caffeine may prevent UV-irradiation-induced photoaging and photocarcinogenesis.

Pharmacognostical Profile

Botanical Name: *Coffea arabica* L.

Synonyms: *Coffea corymbulosa* Bertol.; *Coffea laurifolia* Salisb.; *Coffea moka* Heynh.; *Coffea sundana* Miq.; *Coffea vulgaris* Moench.

Related Species: *Coffea canephora*

Family: Rubiacae

Common Names: Koffee, coffee. Abyssinian coffee, Arabian coffee

African Names: Arab: kassent, kaweh; Kikuyu (Kenya): kahûa/mûhûa; Afaan Oromo (Ethiopia): bunna; Kinyarwanda: kawa; Kirundi: akawa; Runyankore: mwani; Others: kafe, ikawa

Description: The coffee plant occurs naturally as an evergreen, shrub or small tree, up to 5 m tall when unpruned, glabrous, with small glossy leaves. The leaves are simple, alternate, opposite, thin, dark-green, shiny surfaced, fairly stiff; axillary and subaxillary buds often develop into reproductive lateral branches. They are petiolate, sometimes bearing interpetiolar stipules with prominent leaf midrib and lateral veins. The flowers are produced in dense clusters along reproductive branches in the axils of the leaves. They are white, sweet-scented, star-shaped, and carried on stout but short peduncles. Bracteoles unite, forming a cup-shaped epicalyx at the base of the flower. There are five calyx segments halfway along the length, spreading out very widely at the anthesis and five stamens inserted in the corolla tube. Anthers are carried on long, slender, upright filaments. The ovary is inferior, with two united unilocular carpels, each containing a single ovule attached to the base of the carpel wall. The ovary bears a slender style, which terminates in short, pointed bifid stigmas. The fruit is a drupe; pericarp composed of shiny exocarp, fleshy mesocarp, and relatively thin but tough endocarp, in which the seeds are enclosed. Immature berries are dull green; on ripening, the skin color changes through yellow to bright crimson. Each berry contains two seeds, 8.5–12.5 mm long, ellipsoidal in shape, and pressed together by a flattened surface that is deeply grooved; and the outer surface is convex. Thin, silvery testa follows the outline of the endosperm, so fragments are often found in the ventral groove after preparation. Seeds consist mainly of a green corneous endosperm, folded in a peculiar manner, and a small embryo near the base. The coffee berries usually contain two stones (seeds) with their flat sides together but sometimes only a single seed is found inside a fruit, referred to as a "peaberry."

Habitat and Distribution: *Coffea arabica* originated in the southwestern highlands of Ethiopia and the mountainous regions of Yemen, but *C. arabica* is now rare in Ethiopia. It has also been found growing naturally in the Boma Plateau in south Sudan and on Mount Marsabit in northern Kenya. The species is widely naturalized in areas outside its native land—in many parts of Africa, Latin America, the Caribbean, the Pacific, Southeast Asia, and China.

Genetic research has shown that coffee cultivation is threatening the genetic integrity of wild coffee because it exposes wild genotypes to cultivars.[201] The conservation of the genetic variation of *C. arabica* relies on conserving healthy populations of wild coffee in the Afromontane rainforests of Ethiopia.[202] It has been shown that nearly all of the coffee that has been cultivated over the past few centuries originated with just a handful of wild plants from Ethiopia, and today the coffee growing on plantations around the world contains less than 1% of the diversity found in the wild in Ethiopia alone.[203] The plant can tolerate low temperatures, but not frost, and does best with an average temperature between 15°C and 24°C (59°F and 75°F). Commercial cultivars mostly only grow to about 5 m, and are frequently trimmed as low as 2 m to facilitate harvesting. Unlike the closely related *Coffea canephora*, *C. arabica* prefers to be grown in light shade, and in its native Ethiopia, where it is called *būna*, the crop is commonly used as an understorey shrub.[204]

Culinary (Food) Use: Roasted coffee bean is ground and brewed to make one of the two most popular beverages in the world. Coffee is widely used as flavoring in ice creams, pastries, candies, and liqueurs. It can be cooked in butter to make rich flat cakes. It has been used as a masticatory in its native Ethiopia.

Ethnomedicinal Uses: In traditional medicine, it has been used as an analgesic, aphrodisiac, anorexic, antidotal, cardiotonic, CNS stimulant, counterirritant, diuretic, hypnotic, lactagogue, and nervine. Coffee has been reported as a folk remedy for asthma, tropine poisoning, fever, flu, headache, jaundice, malaria, migraine, narcosis, nephrosis, opium poisoning, sores, and vertigo.[205]

Constituents: The most popular content of coffee is caffeine, which occurs in the mature leaves and seeds. Caffeine content varies enormously with Arabica containing 0.8%–1.4% caffeine and Robusta beans contain 1.7%–4% caffeine. Coffee elaborates an abundance of polyphenols and phenolic acids, including chlorogenic acids, caffeoylquinic acids, feruloylquinic acids, dicaffeoylquinic acids, *p*-coumaroylquinic acids, caffeic acid, ferulic acid, and their derivatives. It contains many nonvolatile nitrogenous compounds (including alkaloids, trigonelline, proteins, and free amino acids) and carbohydrates. The lipids found in green coffee include linoleic acid, palmitic acid, oleic acid, stearic acid, arachidic acid, diterpenes, triglycerides, unsaturated long-chain fatty acids, esters, and amides. The total content of lipids in dried green coffee is between 11.7 and 14 g/100 g. The diterpenes found in green coffee include cafestol, kahweol, 16-*O*-methylcafestol, cafestal, and kahweal. Green coffee contains volatile compounds, including short-chain fatty acids, aldehydes, and nitrogen-containing aromatic molecules, such as derivatives of pyrazines. Roasting generates more volatile compounds, some of which produces the characteristic pleasant coffee aroma.

Pharmacological Studies: The most well-known property of coffee is the psychoactive activity of caffeine, an adenosine antagonist that is known for its stimulant effects. Coffee also contains the monoamine oxidase inhibitors β-carboline and harmane, which may contribute to its psychoactivity. Other properties of coffee include the antioxidant activity of the polyphenols, antiproliferation effect, positive effects on mental health, and protective role against cardiovascular diseases. Meta-analyses have suggested that increased coffee consumption is associated with a reduced risk of prostate cancer, including deadlier forms of high-grade prostate cancer. Consuming coffee reduces the risk of skin cancer. Coffee extract and its constituents exhibit antioxidant and anti-inflammatory properties.[206] Coffee extract also diminishes UVB-irradiation-induced photoaging by modulating the MAPK/MMP/type I procollagen pathway.[207] It has been reported that topical application and oral administration of caffeine may prevent UV-irradiation-induced photoaging and photocarcinogenesis. The diterpenes and the other coffee constituents have been shown in *in vitro* experiments to protect liver tissue against chemical oxidation. Coffee constituents have been shown to possess immunomodulatory properties. The unroasted mature or immature coffee beans, referred to as "green coffee bean," are used as health foods and nutritional supplements, and have been clinically studied for the chlorogenic acid content and for possible use for the lipolytic and weight loss properties.

Spent coffee grounds (SCGs), the by-product obtained from roasted coffee beans after water extraction, which have been estimated to be 6 million tons per year worldwide, have been the subject of intense biological evaluations.[208] The water extract of SCG has been shown to possess anti-inflammatory and antiallergic activities,[209] which may be due to the presence of chlorogenic acids and other polyphenols.[210] It has been found that the extraction technique plays a critical role in the recovery of polyphenolic compounds from plant residues. Subcritical water extraction (SWE), also named pressurized hot water extraction, has become a promising option for the isolation of bioactive and nutritional compounds from plants and food materials. Response surface methodology (RSM) has been employed to optimize the SWE of SCGs with an emphasis on the yield of total phenolics and radical-scavenging capacities on 2,2-azinobis-(3-ethylbenzothiazolin-6-sulfonic acid) (ABTS•+) and 1,1-diphenyl-2-picrylhydrazyl (DPPH•+).[211] The optimal conditions for the antioxidant activity of the total phenolic compounds (86.23 mg GAE/g), in terms of ABTS•+ (81.38 mmol TE/100 g) and DPPH•+ (42.13 mmol TE/100 g) scavenging activities were predicted to be in ranges of 160–180°C/37.9–55.0 min/14.1 g/L. The verified TPC

(88.34 mg GAE/g), antioxidant activity on ABTS•+ (88.65 mmol TE/100 g), and DPPH•+ (38.28 mmol TE/100 g) based on superimposing contour plots (179°C, 36 min, and 14.1 g/L) were in good agreement with the predicted data obtained under optimal conditions. 3-*O*-Caffeoylquinic acid, 4-*O*-caffeoylquinic acid, and 5-*O*-caffeoylquinic acid were found to be the major contributor to the antioxidant activities of SCG extract.

Cowpea: Black-Eye Bean

Overview

Cowpea (*Vigna unguiculata*) originated in Africa, where a large genetic diversity of wild types occurs throughout the continent, southern Africa being the richest. It is the preferred pulse in large parts of Africa. Cowpea is perhaps sub-Saharan Africa's most widely planted native legume and the second most important grain legume continent-wide; only peanut—a native of the Americas—occupies more African farmland. West Africa's farmers alone grow cowpea on an estimated 6 million hectares. More than 95% of the world crop comes from that area; Nigeria, the biggest producer, grows an amount variously estimated at several million tons a year. Cowpea is rich in proteins, amino acids, vitamins, minerals, and polyphenols. It also contains flavonols, mainly di- and monoglycosides of quercetin, myricetin and kaempferol glycosides, as well as anthocyanins such as delphinidin-3-*O*-glucoside and cyanidin-3-*O*-glucoside. Cowpea extracts possess antioxidant activity and showed the ability to inhibit free-radical-induced DNA damage. Available evidence suggests that cowpea protein, probably through its peptides, is a functional food able to reduce hypercholesterolemia, a major cause of cardiovascular diseases. It has been shown by several studies that the protein isolated from the cowpea interferes with lipid homeostasis, resulting in a significant reduction of total and non-HDL cholesterol, either in hamsters or in clinically hypercholesterolemic patients. It is interesting to note that enzyme digests of cooked cowpeas that inhibited radical-induced DNA damage suggest that cowpea phenolics retain some radical-scavenging activity after gastrointestinal digestion. Furthermore, cooking and enzyme digest did not hamper the ability of cowpea protein to inhibit the enzyme HMGCR (3-hydroxy-3-methylglutaryl coenzyme A reductase) and reduced cholesterol micellar solubilization *in vitro*. The enzyme HMGCR is a rate-determining step in hepatic cholesterol production and it is the target of several drugs aimed at the control of high cholesterol levels. Cowpea also has hypoglycemic activity.

Pharmacognostical Profile

Botanical Name: *Vigna unguiculata* (L.) Walp.

Synonyms: *Vigna sinensis* subsp. *sesquipedalis* (L.) van Eseltine; *Dolichos unguiculatus* L.; *Vigna catjang* (L.) Walp.; *Vigna pubescens* R.Wilczek; *Vigna sesquipedalis*; and 136 other synonyms

Family: Fabaceae

Common Names: Black-eye bean, black-eye pea, China pea, marble pea, yard-long bean, asparagus bean, Bombay pea, catjang cowpea

African Names: Sierra Leone: kroo bean; Ethiopia: adanguari, nori, Igbo (Nigeria): agwa, akidiani; Acholi and Luo (Uganda): amuli, boo-ngor, omugobe, boo; Tonga (Zambia): ilanda; Shona: nyemba; Ndebele, Zulu: ndlubu; Setswana (Botswana): dinawa, nyeru; Luo (Kenya): boo; Swahili: kunde; Kikuyu: thoroko; Mauritius: voehme; Nyiha (Tanzania): nkunde; Sesotho (Lesotho): linaoa; Northern Sotho (South Africa): dinawa; Tumbuka (Malawi): nkunde; Chewa: khobwe; SiSwati (Swaziland): tinhlumayi; Seychelles: brenm; Namibia: omakunde, olunya, omandume, ongoli; Zimbabwe: nyemba, kanyangube, tinyawo

Description: There are many different landraces, cultivars, and varieties of cowpea, varying in growth habit from erect or semiupright to spreading and climbing. The seeds are characteristic in having a marked white hilum surrounded by a dark ring. The most commonly grown are the white types or those with a black mark around the hilum, the latter being called "black-eyed." Pods of most varieties hang downward but in some they point sideways or upward. They are generally an annual crop, climbing, trailing, or more or less erect annual or perennial herb, cultivated as an annual; taproot well developed, with many lateral and adventitious roots; stem up to 4 m long, angular or nearly cylindrical, slightly ribbed. The species is largely self-pollinating, but up to 2% outcrossing has been reported. The leaves are alternate, three-foliolate; stipules ovate, 0.5–2 cm long, spurred at base; the petiole up to 15(–25) cm long, grooved above, swollen at base, rachis (0.5–)2.5–4.5(–6.5) cm long; stipels small; leaflets ovate or rhombic to lanceolate, (1.5–)7–14(–20) cm × (1–)4–10(–17) cm, basal ones asymmetrical, apical one symmetrical, entire, sometimes lobed, glabrous or slightly pubescent, three-veined from the base. The flowers may be purple, pink, white, blue, or yellow. Pods tend to be long, smooth, cylindrical, and somewhat constricted between the seeds; between 8 and 20 seeds occur per pod. They are globular to kidney-shaped, 5–12 mm long, smooth or wrinkled, and ranging in color from white, cream, or yellow to red, brown, or black, while some are speckled or blotched.



Habitat and Distribution: Cowpea is native to Africa. The greatest genetic diversity of cultivated cowpea is found in West Africa, in the savanna region of Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, and Cameroon. About 80% of the total world production of cowpea comes from Nigeria. The other African growing countries include

Niger, Senegal, Mauritania, Mali, Burkina Faso, Côte D'Ivoire, Ghana, Benin, Togo, Chad, Cameroon, Central African Republic, Congo, Uganda, Tanzania, Sudan, Ethiopia, Kenya, Angola, Somalia, Zambia, Mozambique, Zimbabwe, Botswana, Namibia, South Africa, and Madagascar. It is however not a prominent crop in humid Central Africa. Cowpea is also cultivated in tropical parts of Asia and Latin America.

Cowpea Cultivars: As noted earlier, cowpea is extremely variable, both in wild and cultivated plants. Several subspecies (up to 10) have been distinguished, most of them comprising perennial wild types, but subsp. *unguiculata* include annual wild types and cultivated ones. PROTA has listed the following five cultivar groups as generally recognized among the cultivated *Vigna unguiculata*, although the groups can be crossed readily and overlap:

- Unguiculata group (common cowpea): Pulse and vegetable types, grown for the dry or immature seeds, young pods or leaves; plant habit prostrate to erect, up to 80 cm tall, late flowering, pods 10–30 cm long, pendent, hard and firm, not inflated when young, many-seeded and seeds not spaced; most African cultivars belong to this group.
- Sesquipedalis group (yard-long bean, synonyms: *Dolichos sesquipedalis* L., *Vigna sesquipedalis* (L.) Fruhw.): Grown for the young pods; plant climbing, stem up to 4 m long, pods 30–120 cm long, pendent, inflated when young, many-seeded and seed spaced; important vegetable in South-East Asia, but of minor importance in tropical Africa, where only cultivars introduced from Asia are grown.
- Biflora group (catjang cowpea): Grown for the seeds and tender green pods, and for fodder; plant habit prostrate to erect, up to 80 cm tall, early flowering, pods 7.5–12 cm long, erect or ascending, hard and firm, not inflated when young, few-seeded and seeds not spaced; important in India and South-East Asia, locally also in Africa (e.g., Ethiopia).
- Melanophthalmus group: Originating from West Africa; plant able to flower quickly from the first nodes under inductive conditions, pods comparatively few-seeded, seed coat thin, often wrinkled, partly white.
- Textilis group: A small group only grown in Nigeria for the fiber extracted from the long peduncles; at the beginning of the twentieth century, this group was distributed from the interior delta of the Niger river eastward to the Lake Chad basin, but it is gradually disappearing. (Adapted from PROTA4U).[4]

Culinary (Food) Use: Cowpea is a staple in many parts of Africa. The mature seeds are cooked and eaten alone or together with vegetables, spices, and often palm oil, to produce a thick bean soup. Many cowpea-based cuisines are eaten in West Africa, where the seeds are decorticated and ground into a flour and mixed with chopped onions and spices and made into cakes, which are either deep fried ("akara balls") or steamed ("moin moin"). Cowpea flour has been processed into crackers, composite flour, and baby foods in Senegal, Ghana, and Benin. The leaves and the immature seeds and pods of cowpea are eaten as vegetables. The roots are sometimes eaten, for example, in Ethiopia and Sudan. The dry seeds have been used as a coffee substitute.

Ethnomedicinal Use: Cowpea is used extensively in traditional medicine; externally as poultice prepared from the leaves and seeds to treat swellings, skin infections, and insect stings. The root decoction is used for the treatment of epilepsy, chest pain, constipation, and dysmenorrhea. Aerial parts of the plant have been used as a sedative in tachycardia and as an anodyne.

Constituents: Cowpea is rich in proteins, amino acids, vitamins, minerals, and polyphenols. The seed contains (g/100 g): 24.5 protein, 51.4 carbohydrate, 16.6 insoluble fiber and 2.7 soluble fiber, and 2.6 ash; major mineral constituents (mg/100 g) were 6.8 iron, 4.1 zinc, 1.5 manganese, 510.0 phosphorus, and 1430.0 potassium. Lipid content was 2.2%. Its fatty acid profile was 29.4% saturated and 70.7% unsaturated. The caloric value is approximately 323.4 kcal/100 g of seeds.[212] The essential amino acid composition per 100 g mature, raw cowpea seeds is tryptophan 290 mg, lysine 1591 mg, methionine 335 mg, phenylalanine 1373 mg, threonine 895 mg, valine 1121 mg, leucine 1802 mg, and isoleucine 956 mg. The principal fatty acids are per 100 g edible portion: linoleic acid 343 mg, palmitic acid 254 mg, linolenic acid 199 mg, and oleic acid 88 mg. Cowpea protein is relatively rich in lysine, but poor in S-containing amino acids. Cowpea seed is lower in antinutritional components such as lectins and trypsin inhibitors than the common bean (*Phaseolus vulgaris* L.), and is easier and quicker to cook. The phenolic acids such as protocatechuic acid, *p*-hydroxybenzoic acid, caffeic acid, *p*-coumaric acid, ferulic acid, 2,4-dimethoxybenzoic acid, and cinnnamic acid have been identified in cowpea.[213] It also contains flavonols, mainly di- and monoglycosides of quercetin, as well as myricetin and kaempferol glycosides, as well as anthocyanins such as delphinidin-3-*O*-glucoside and cyanidin-3-*O*-glucoside.[214]

The phenolic composition of acetone extracts and enzyme digests of cooked cowpea has been determined using UPLC–MS to identify the following compounds: *p*-hydroxybenzoic acid, *p*-coumaric acid, coumaroylaldaric acid, and feruloylaldaric acid in the acetone extracts of the cooked cowpea but not detected in the enzyme digests. Glycosides of quercetin and myricetin decreased upon *in vitro* gastrointestinal digestion of cooked cowpeas, whereas flavan-3-ols were hardly present except catechin glucoside.[215]

Pharmacological Studies: Cowpeas extracts possess antioxidant activity and showed the ability to inhibit free-radical-induced DNA damage.[215] Available evidence suggests that cowpea protein, probably through its peptides, is a functional food able to reduce hypercholesterolemia, a major cause of cardiovascular diseases.[216] It has been shown by several studies that the protein isolated from the cowpea interfere with lipid homeostasis, resulting in a significant reduction of total and non-HDL cholesterol, either in hamsters or in clinically hypercholesterolemic patients.[217] In a study that simulated human digestion, it was found that peptides liberated from raw and cooked cowpea protein inhibited routes that interfere in the *in vitro* lipid metabolism. Protein and peptides of cowpea are able to inhibit the enzyme HMGCR (3-hydroxy-3-methylglutaryl coenzyme A reductase) and reduced cholesterol micellar solubilization *in vitro*. However, these findings do not exclude the possibility of other mechanisms being involved. The most common processing for cowpea consumption decreased the inhibitory action of peptides on HMGCR and increased their ability to insolubilize micellar cholesterol. The antioxidant potential of this protein is related to peptides with molecular mass below 3 kDa. In contrast, thermal processing was responsible for a significant decrease of this capacity.[218] The enzyme HMGCR is a rate-determining step in hepatic cholesterol production and it is the target of several drugs aimed at the control of high cholesterol levels.

Some cultivars of cowpea have also been shown to exhibit hypoglycemic activity on laboratory animals.[219] A protein isolate from cowpea sprout has been subjected to *in vivo* bioassay on Sprague–Dawley male rats to determine any possible hypocholestrolemic properties of the sprout. Normal and diabetic rats were given standard or cowpea protein isolate feed. Blood triglycerides, total cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) of rats were analyzed on the third day and every 3 days for 2 weeks. The result showed that the blood triglyceride, total cholesterol, and LDL decreased and the blood HDL increased in diabetic rats with protein isolate treatment. The potency

of hypocholestrolemic activity was shown by the ratio of total cholesterol /HDL and LDL/HDL. The ratio of the rats was normal with the exception of the group of diabetic rats that were given standard feed.[220]

Composite formulations of maize and cowpea, cow pea and sorghum, and cowpea and pigeon pea for the preparation of porridges are available in the market and many scientific investigations have been carried out to determine the functional benefits of such composites. For example, the effect of compositing red nontannin sorghum with brownish-cream cowpea and *in vitro* gastrointestinal digestion on total phenolic and flavonoid contents and antioxidant properties of a sorghum–cowpea composite porridge studied using maize–soybean composite porridge was used as a reference sample. The antioxidant properties were studied using radical-scavenging activities against the 2,20-azino-bis(3-ethyl benzothiazoline-6-sulfonic acid), peroxyl, and NO radicals as well as inhibition of LDL oxidation and oxidative damage of vector DNA. Hydroperoxide content of the samples was also measured. All the samples demonstrated radical-scavenging activity. Simulated duodenal digests of the porridges had hydroperoxides and therefore caused LDL oxidation. The undigested porridges and simulated gastric digests inhibited LDL oxidation. It was found that compositing the cereals with legumes increased total phenolic and flavonoid contents and NO-scavenging activity of their porridges.[221] *In vitro* gastrointestinal digestion of the porridges increased their total phenolic and flavonoid contents, radical-scavenging activities, and LDL oxidation inhibitory activity.[221]

Egyptian Chamomile: Msolo

Overview

Egyptian chamomile is a caffeine-free tea obtained from the flowering tops of *Matricaria* and consumed globally for its soothing effect. It yields a pleasant-smelling volatile oil, ca. 2% of the dry weight of the flowers. The sesquiterpene α-bisabolol comprises up to 50% of the volatile oil. Other components of the volatile oil include chamazulene, guiazuline, farnescene, α-bisablol derivatives, and matricine. The plant also contains flavonoids apigenin, luteolin, patuletin, and quercetin, and related glycosides, as well as coumarins, spiroethers, and polysaccharides. Four different chamomile chemotypes can be distinguished depending on the composition of the volatile oil: chemotypes with or without chamazulene (European origin), those with α-bisabolol (Portuguese and Spanish origin), with α-bisaboloxide A (African, Bulgarian, and Turkish origin), with α-bisaboloxide B (Argentine origin). It has anti-inflammatory, antiproliferation, and antimicrobial properties. The Egyptian chamomile is effective as a mild night-cap and a carminative. The azulenes found in chamomile have been shown to be antiallergenic and anti-inflammatory. One of its major constituents, α-bisabolol, has anti-inflammatory, antibacterial, antimycotic, and ulcer-protective properties. The compound was also found to inhibit ulcer development in experimental animals induced by indomethacin, stress, and ethanol, and reduced the healing times for ulcers.

Pharmacognostical Profile

Botanical Name: *Matricaria recutita* L.
Synonyms: *M. chamomilla* L.; *M. suaveolens* L.

Family: Compositae

Common Names: Matricaria flowers, German or Hungarian chamomile flowers

African Names: Arabic: bahboonig; Xhosa: msolo

Description: The flowers of *Matricaria* could be differentiated from those of the English chamomile by their hollow receptacle, which is devoid of paleae. The capitulum spreads out to 10–17 mm in diameter and consists of an involucre, up to 20 marginal ligulate florets and many central tubular florets. Comparatively, *Matricaria* has smaller flower heads than chamomile. It has bitter and aromatic taste but the odor is usually weaker than those of Roman chamomile.

Habitat and Distribution: The plant is largely a Mediterranean crop but grows well in north Africa and the cooler regions of south and eastern Africa.

Culinary (Food) Use: Chamomile is used as a tea.

Ethnomedicinal Uses: African chamomile is reputed as an herbal tea and is dispensed as a sedative, carminative, antiseptic, analgesic, antispasmodic, and anti-inflammatory. It has been used for the treatment of gout, indigestion, diarrhea, and insomnia, and in pediatric practice for infantile convulsions, colic, and teething pains.[3]

Constituents: It yields a pleasant-smelling volatile oil, with the sesquiterpene α-bisabolol comprising up to 50%. The volatile oil content is about 2% of the dry weight of the flowers. Other components of the volatile oil include chamazulene, guiazuline, farnescene, α-bisablol derivatives, and matricine.[222,223] The plant also contains the flavonoids apigenin, luteolin, patuletin, and quercetin, and related glycosides.[224] Coumarins, spiroethers, and polysaccharides have been shown to be present in *Matricaria.*

At least four types of the herb can be distinguished depending on the composition of the oil: chemotypes with or without chamazulene (European origin), those with α-bisabolol (Portuguese and Spanish origin), those with α-bisaboloxide A (African, Bulgarian, and Turkish origin), and those with α-bisaboloxide B (Argentine origin).[225]

Pharmacological Studies: Extracts and tincture of the plant have been shown to possess many and varied pharmacological properties due to its many biologically active compounds. It appears that the anti-inflammatory activity is the predominant effect of *Matricaria* extract when applied externally, and smooth muscle relaxing effects predominate when taken internally. The azulenes of both species of chamomile have been shown to be antiallergenic and anti-inflammatory.[226] One of its major constituents α-bisabolol has been shown to have anti-inflammatory, antibacterial, antimycotic, and ulcer-protective properties. The compound was also found to inhibit ulcer development in experimental animals induced by indomethacin, stress, and ethanol, and reduced the healing times for ulcers induced by chemical stress or heat coagulation.[227] Natural (–)-α-bisabolol has been shown to be more effective than the synthetic racemic bisabolol in healing burns; it also decreases the temperature of skin exposed to UV light. Bisabolol has a spasmolytic activity comparable to that of papaverine. Other constituents of *Matricaria* with spasmolytic activity include apigenin (2–5 times the activity of papaverine), apiin, patuletin, bisaboloxide A and B, and the *cis*-spiroethers (10 times as active papaverine). The wound-healing property of the drug is aided by the immunostimulating activity of the polysaccharides, which activate macrophages and B lymphocytes.[228] In a comparative evaluation, *Matricaria* ointment (Kamillosan) was found to be more effective in experimentally induced toxic contact dermatitis than the ointment base or 0.1% hydrocortisone acetate ointment; the topical preparation was assayed by a profilometry determination of the structural changes of the epidermal surface.[229] A formulation consisting of Egyptian chamomile and ocimum is manufactured by Intercedd Health Products (Nigeria) for the relief of premenstrual syndrome.

Toxicity: The drug has low toxicity. The acute LD_{50} of the volatile oil is approximately 15 mL/kg in rats and mice. The teas prepared from pollen-laden flower heads cause contact dermatitis and anaphylaxis on hypersensitive individuals.[230,231] Sensitivity to *Matricaria* has been ascribed to type I IgE-mediated immunologic response, and persons suffering from pollen-induced hay fever are particularly susceptible.[232] Cross-reactivity has been demonstrated among chamomile tea extract and the pollens of *Matricaria*, *Ambrosia trifida* (giant ragweed), and *Artemisia vulgaris* (mugworth) using the ELISA inhibition study.

Enset

Overview

Enset (*Ensete ventricosum*) is a member of the banana family, but unlike banana, enset is not grown for its fruit but for the starchy pulp in its trunk, which on the largest specimens can be a meter in diameter and 3 m tall, filled with starchy pith. The corm, the underground portion of the stem that resembles a potato, may be almost a meter long and a meter in diameter and is packed, like some giant potato, with starch. It is cultivated in Ethiopia but grows wild in many parts of Africa. Enset is increasingly being recognized as a healthy food and served in many restaurants in Ethiopia. The plant is perhaps the biggest vegetable of all. The giant stem and the thick immature leaf stalks can be cooked like a vegetable and is said to taste like cooked celery. Enset also yields good flour from the milky white pulp, known as "bulla," obtained by scraping it off the inner leaf tissues. Dough made from this starch-filled flour is turned into many things, including enjera, porridge, and dumplings. The mixture of scraped pseudostem pulp and the pulverized corm and stalk of the inflorescence is put into a pit for fermentation and the resulting product is locally called "kocho." The leaves are rich in polyphenols, especially anthocyanins. It also contains amino acids, proteins, and vitamins. The roots and rhizome have been shown to contain phenylphenalenones. The wild banana is used as a meal for diabetics and people suffering from metabolic dysfunction. Not many pharmacological studies have been carried out on this species.

Pharmacognostical Profile

Botanical Name: *Ensete ventricosum* (Welw.) Cheesman

Synonyms: *Musa ensete* J.F.Gmel., *Musa ventricosa* Welw., *Ensete edule* Bruce ex Horan.

Family: Musaceae

Common Names: Enset, false banana, Ensète, wild banana

African Names: Ethiopia: enset, guna-gunaf (Amhara), asat (Gurage), weise (Kambata), and wassa (Sidama), kocho (G), koda (Am/Sodo/Oromo), werke, wesa (Oromo), *aquimi* (*Ari*); Malawi: chizuzu (Ch); South Africa: Afirikaanse wilde-piesang (Afrikaans), motholo (Pedi), mulala (Venda); Kenya: ndizi mwitu (Swahili), makulutui (Ka); Zimbabwe: mubhanana mufigu, dzoro, hovha

Description: Enset resembles a banana plant. It is a gigantic herb, usually larger than banana; its leaves are more erect, and shaped somewhat more like a lance head. They are

spirally arranged and bright green with a striking red midrib. It is a monocarpic, perennial herb 4–8(–11) m tall, with pseudostem formed of overlapping leaf sheaths, swollen at the base, the underground portion consisting of a corm 0.7–1.8 m long, with a circumference 1.5–2.5 m at maturity; and a root system that is usually adventitious. The leaves are arranged spirally, arising from the apex of the corm, with elongated leaf sheaths; lamina oblong to oblanceolate-oblong, up to 5 m × 1.5 m, entire, with strongly channeled midrib and many parallel lateral veins, bright to dark green; the midrib, petiole, and margin sometimes pale to dark red or dark purple, the lower side rarely being reddish. The inflorescence is a terminal thyrse growing up through the center of the pseudostem and thus appearing to arise from its apex, bearing cincinnate flower clusters in axils of spathaceous bracts on an indeterminate main axis, the exserted part of the inflorescence commonly 1–2 m long, drooping. The flowers are unisexual, zygomorphic, functionally female ones on the proximal part of the inflorescence, male ones on the distal part; male flowers with one three-lobed outer tepal up to 5.5 cm long, white with orange-yellow tips, one serrate-apiculate inner tepal, five up to 5 cm long stamens having violet to purple anthers, sometimes also with a staminode up to 1 cm long, and a slender style up to 2 cm long; female flowers with one deeply three-lobed outer tepal up to 5.5 cm long, 1–3 inner tepals variable in shape with two wings and an apiculum up to 1.5 cm long, 0–5 more or less rudimentary stamens, and an inferior, three-celled ovary bearing a style 2.5–4 cm long, with a large capitate stigma. (Adapted from PROTA.[205])

Habitat and Distribution: Ethiopia is the only place where the species has been domesticated. The wild type occurs from Nigeria in West Africa through the central to the southern parts of the continent, including Transvaal, Angola, Zimbabwe, and Mozambique. The wild form occurs at lower altitudes than the present area of enset cultivation in Ethiopia.

Culinary (Food) Use: The plant is consumed in Ethiopia, notably among the Gurage, Sidama, Gamo, Hadiya, and Wolayta peoples. The young and succulent enset parts can be boiled like cabbage or artichoke. The giant stem made of overlapping layers of rolled-up leaves, and the thick immature leaf stalks are cut into small pieces and boiled, and they taste like cooked celery. In addition, the immature pith can be extracted from inside the stem and boiled as a vegetable. Enset also yields good flour from the milky white pulp, known as "bulla," obtained by scraping it off the inner leaf tissues. Dough made from this starch-filled flour is turned into many things, including enjera, porridge, and dumplings.[233] The mixture of scraped pseudostem pulp and the pulverized corm and stalk of the inflorescence is put into a pit for fermentation and the resulting product is locally called "kocho."

Ethnomedicinal Uses: Enset is used to treat broken bones. A decoction of pounded leaves has been used to stimulate labor or induce abortion. Ash and infusions from the fruits and leaves have been used to treat hepatitis and other liver complaints.

Constituents: The petroleum ether extract of dried seed powder yielded fatty oil and triterpenoid esters. The leaves are rich in polyphenols, especially anthocyanins. The seeds of *E. superbum* Cheesm showed the presence of phosphates, and traces of alkaloids, glycosides, and sugars.[234] It also contains amino acids, proteins, and vitamins. The roots and rhizome have been shown to contain phenylphenalenones.[235]

Pharmacological Studies: Not much pharmacological investigation has been carried out on the African *Ensete* species. The related Asian *E. superbum* has been shown to possess the following activities: antiviral, cardiovascular, cholinergic, hypnotic and sedative effects, respiratory, hypoglycemic and antiglycemic effects, antifertility, and coagulant and anticoagulant.[236]

Ethiopian Pepper

Overview

Ethiopian pepper consists of the fruits of the African spice, *Xylopia aethiopica*, an evergreen, aromatic tree growing up to 20 m high, 50 cm in diameter, with a straight bole. The fruits yield a very aromatic essential oil, which contains α- and β-pipenes, careen, cymene, α-phellandrene, limonene and terpinoline, cineole, bisabolone, linolool, terpinen-4-ol, terpineal, cuminyl alcohol, and cumminic aldehyde. The fruit also contains the diterpenic acid, xylopic acid [15β-acetoxy (–) 16ene-19-oic acid], and its analogs kaurenoic, 15-oxo-kaurenoic acid, and kauran-16-α-ol. *Xylopia* is employed extensively in African traditional medicine for the treatment of a plethora of illnesses. The extracts of *Xylopia aethiopica* have been shown to possess significant antimicrobial, antioxidant, cardiovascular, and antidiuretic effects. The extracts were subjected to bioassay-directed phytochemical examination, which showed that the diterpene kaurenoids in the extracts were responsible for the significant systemic hypotensive and coronary vasodilatory effect accompanied with bradycardia. These effects were attributed to calcium antagonistic mechanism. The diuretic and natriuretic effects found were similar to the effects of chlorothiazide; this suggests inhibition of Na^+ and K^+ reabsorption in the early portion of the distal tubule. It also has the ability to reduce the intraocular pressure in glaucoma patients.

Pharmacognostical Profile

Botanical Name: *Xylopia aethiopica* (Dunal) A. Rich.

Synonyms: *Annona aethiopica* Dunal.; *Xylopia emenii* Engl.

Family: Annonaceae

Common Name: Ethiopian pepper

African Names: Arabic: kyimba; Bini: unien; Hausa: kimba; Igbo: uda; Nupe: tsunfyanyi; Yoruba: erunje; Efik: atta; Ibibio: ata

Description: *Xylopia* is an evergreen, aromatic tree growing up to 20 m high, 50 cm in diameter, with a straight bole. The bark is grayish brown to reddish, fairly smooth but with a network of fissures. The slash is reddish brown and fibrous beneath; the crown is much branched, the branches and branchlets having numerous white lenticels. The leaves are broad (5–15 cm long and 2.5–6 cm wide), acuminate, elliptic, simple, with stipules absent; the margins are entire, coriaceous, midrib very broad at the base, slightly impressed above. The flowers are greenish white, solitary or in small clusters of 3–5. There are six petals, in two whorls, cream, with outer petals linear, 2.5–5 mm long, thick, gradually tapering to the apex, covered with rust-colored hairs, and the inner petals shorter and narrower. The fruits are peppery and occur as monocarp, cylindrical, up to 9 cm long, reddish at first, eventually blackish, with 1–8 orange red to black, cylindrical seeds.[3]

Habitat and Distribution: *Xylopia eathiopica* is native to the lowland rainforest and moist fringe forests in the savanna zones of Africa. It is distributed from Senegal to Zaire, and has been located in Gambia, Angola, Guinea, Sierra Leone, Liberia, Ivory Coast, Togo, Benin, Nigeria, Gabon, Zaire, Sudan, Uganda, Tanzania, Zambia, and Mozambique.

Culinary (Food) Use: It is used as a spice for soups, sauces, and stews.



Ethnomedicinal Uses: The fruit of *Xylopia* is used as a soup condiment and is valued for its carminative effect and as a cough remedy. The Igbo give the soup to women to promote fertility or after childbirth as a general tonic and to promote healing and lactation. It is an ingredient in the preparation of a Yoruba herbal remedy, agbo. A decoction of the fruit is drunk as a remedy for stomachache and a treatment for bronchitis, biliousness, and dysentery. The seed extract is used to eliminate roundworms.[1] A decoction of the fruits of *X. aethiopica*, leaves of *Alstonia boonei*, and *Wissadula amplissima* is used to bathe children as an anticonvulsant. A decoction of the fruits and stem bark of *Newbouldia laevis* is drunk as a remedy for amenorrhea. The fruit has been used against cough, stomachache, dizziness, amenorrhea, bronchitis (when smoked and inhaled), dysentery, enema, bulimia (eating disorder), lumbago, and neuralgia. It is also used as a calmative, purgative, and repulsive to pain, and in the treatment of boils and skin eruptions; it is mixed with its roots to treat rheumatism.[237]

The external uses of the plant include a poultice for headache and neuralgia, and with lemongrass as a douching solution for female hygiene. A soup prepared with the ground fruits, those of *Piper guineense*, and leaves of *Leptapsis cochleats*, is taken as a remedy for dizziness.

Constituents: The fruits contain the diterpenic acid, xylopic acid [15β-acetoxy (–) 16ene-19-oic acid], and its analogs kaurenoic, 15-oxo-kaurenoic acid, and kauran-16-α-ol.[238,239] The plant also yields cuminal, acyclic compounds, glycosides, alkaloids, fats, oils, and a pleasant-smelling volatile oil.[240,241] The volatile oil contains α- and β-pipenes, careen, cymene, α-phellandrene, limonene and terpinoline, cineole, bisabolone, linolool, terpinen-4-ol, terpineal, cuminyl alcohol, and cumminic aldehyde.[242]

Pharmacological Studies: The fruit extract has been shown to be antimicrobial against both Gram-positive and Gram-negative bacteria, but inactive against certain strains of *Escherichia coli*, the activity mainly due to the diterpene xylopic acid,[4,243,244] as well as antifungal activity.[177,245]

The combination of dried fruit extract from *Xylopia aethiopica* and vitamin C has been evaluated for its effect against γ-radiation-induced liver and kidney damage in male Wistar rats. The combination product increased the antioxidant defense systems in the liver and kidney of irradiated animals, and may protect from adverse effects of whole-body radiation.[246] Insecticidal formulations based on the essential oil of *Xylopia aethiopica*

(Annonaceae) and kaolinite-clay (particles size less than 50 μm) were effective in protecting stored grains. Ingestion-contact insecticide tests have been conducted using the maize weevil *Sitophilus zeamais* (Motsch.) (Curculionidae). The activity was found to be concentration dependent with the lethal concentration producing a 50% mortality rate (LC_{50}) at 4.35% (w/w).[247] It also showed antifeedant activity against workers of the subterranean termite, *Reticulitermes speratus*. Both the hexane extract of *Xylopia aethiopica* fruits and aqueous methanol extract of the seeds showed termite antifeedant activity. Bioassay-directed fractionation led to the isolation and identification of six ent-kaurane diterpenes in the active hexane extract. Feeding deterrent activity varied significantly with the structures when the compounds were tested at concentrations ranging from 5000 ppm (40 μg/cm^2) to 100 ppm (0.824 μg/cm^2). (–)-Kaur-16-en-19-oic acid had the strongest termite antifeedants activity among the ent-kauranes isolated.[248]

The extracts of *Xylopia aethiopica* have been shown to possess significant cardiovascular and antidiuretic effects.[249] The extracts were subjected to bioassay-directed phytochemical examination, which showed that the diterpene kaurenoids in the extracts were responsible for the significant systemic hypotensive and coronary vasodilatory effect accompanied with bradycardia. These effects were attributed to a calcium antagonistic mechanism. The diuretic and natriuretic effects found were similar to the effects of chlorothiazide; this suggests the inhibition of Na^+ and K^+ reabsorption in the early portion of the distal tubule. Further experiments are needed to elaborate the exact mechanisms of the hypotensive and diuretic effects of diterpene kaurenoids.

The ocular dynamics of bolus consumption of 300 mg total dose has been studied on visually active volunteers with a view to finding its ocular effects or complications. It was found that the aqueous extract of *X. aethiopica* was neither miotic nor mydriatic, but lowered the intraocular pressure (17.48%), reduced the near point of convergence (31.1%), and increased the amplitude of accommodation (8.98%), which are positively correlated ($r = 0.95$). On the other hand, the systemic extract had no effect on the visual acuity at far and near as well as the phoria status at the appropriate distances. The convergence excess resulted in esophoria and the increased amplitude of accommodation placed a greater demand on the accommodation mechanism without any discomfort. The nonspecific mechanism of action makes it a safer spice, which can be exploited in the management of exophoria and raised intraocular pressure (glaucoma) in instances where the efficacy of the older conventional drugs is insufficient.[250] Xylopia extracts also possess significant antidiabetic,[620] anti-inflammatory,[621] and antidepressant[622] properties.

False Nutmeg

Overview

The false nutmeg is a tall tree, up to 33 m high and about 3 m in girth. The bole is long and straight; cylindrical and without buttress roots. It produces aromatic seeds used as a soup condiment in many parts of Africa. The stem bark contains allantoin and the isoflavones 7,4′-dimethoxy-2′-hydroxyisoflavone and 2′-hydroxyformononetin. It possesses antidiabetic, cancer, anthelmintic, and antiprotozoan activities. The plant has also been found to be active against microbes, including *Helicobacter pylori*, ulcers, and body pains.

Pharmacognostical Profile

Botanical Name: *Pycnanthus angolensis* Welw.
Synonym: *P. combo* Warb.
Family: Myristicaceae
Common Names: False nutmeg tree, African nutmeg, wild nutmeg
African Names: Abe: walele; Bakwari (Duala, Bosamba, Nasamba, Bakoosi): ngosame; Basa: dihin; Bini: moghan; Efik: abakang; Ibibio: abakang; Fanti: edua; Igbo: egwu-noma, egiri oma; Mende: gboyei; Nupe: kpokogi; Nzima: tika; Timme: pompon; Yoruba: akomu
Description: A tall tree, up to 33 m high and about 3 m in girth. The bole is long and straight; cylindrical and without buttress roots. The bark is reddish-gray, scaly, and fissured lengthwise. In old trees, the bark flakes off in patches. The slash is reddish and exudes a sticky, honey-colored latex that turns red later. The branches are in two whorls, the twigs and leaves are covered with rust-colored, woolly hairs. The leaves are leathery in texture, with a smooth upper surface; the lower surface is covered with rust-colored hairs, which disappear with age; they are generally riddled with holes caused by insects, simple, 15–21 cm long and 5–9 cm broad, with nearly parallel margins. They have a short apex and short and heart-shaped base. The midrib is very prominent on the lower surface. The stalk is thick and about 1.5 cm long. The flowers are small, brownish-red, in small crowded heads, falling in masses around the base of the tree; male and female are borne at different times; there are irregularly branched common stalks, which may be as long as 7–15 cm. The flower stalks are among the leaves or slightly below them. The fruits are egg-shaped or almost round, 2–3 cm long and 1.5–2 cm in diameter. The shells are rather hard and split longitudinally into two valves, exposing solitary seeds with bright red arils, which turn brownish with time.[4]



Habitat and Distribution: A lowland rainforest tree, common in secondary forests, the false nutmeg is distributed throughout the west coast of Africa, in Chad, Ethiopia, and parts of Somalia, Zambia, and Zaire.
Culinary (Food) Use: The seeds are aromatic and are used as a soup condiment in many parts of Africa.

Ethnomedicinal Uses: The seed fat is applied together with the reddish latex on skin diseases. The bark is pounded and drunk with palm wine for loss of appetite. The twigs are sucked to cure sores in the mouth. The root infusion is used with extracts of *Cassia occidentalis* and Guinea grains as an anthelmintic. In Nigeria, the seeds are used for the preparation of mouthwash for the treatment of "thrush." The twigs are used as chewing sticks, for the treatment of toothache, and applied externally for various skin diseases in Nigeria. It is also useful in the treatment of headache, sore throat, ulcers, and wounds.[1]

Constituents: It contains allantoin, kombic acid, 7,4′-dimethoxy-2′-hydroxyisoflavone, 2′-hydroxyformononetin, dihydroguaiacetic acid, pycnanthuquinone A and B, and pycnanolide A and B.

Pharmacological Studies: *Pycnanthus angolensis* has been shown to possess antidiabetic, anthelmintic, and antiprotozoan activities, as well as anticancer properties.[251] The plant has also been found to be active against microbes, including *Helicobacter pylori*, ulcers, and body pains. The stem bark extract of *Pycnanthus* has been investigated for its antinociceptive and antiulcer activities.[252] In one study, the antinociceptive activity was evaluated in acetic acid-induced writhing, formalin, and tail immersion tests in mice while antiulcer activity was evaluated in ethanol- and indomethacin-induced models in rats. It was found that in the acetic acid-induced writhing test, the extract (50, 100, and 150 mg/kg, p.o.) significantly reduced the number of writhes (46.75%, 57.28%, and 75.69%), respectively, compared to the control. The extract significantly ($P < 0.001$) reduced the time spent in licking the hind paw at both phases in the formalin test. In the tail immersion test, significant antinociceptive effect was only observed with the dose of 150 mg/kg, with peak effect at 90 min (43.38%). There was no significant change in the spontaneous locomotor activity of animals in the open field. The extract prevented the gastric ulceration caused by ethanol and indomethacin treatments compared to the control.

Fenugreek

Overview

Fenugreek, *Trigonella foenum-graecum*, is an aromatic leguminous plant containing an edible oil with its characteristic pungent odor. It is an introduced crop that is used as an important spice in food and traditional medicine. The dried seeds of the plant have extensive application in foods and beverages as a flavoring additive. It contains amino acids and a protein fraction that is found to be lysine-rich and comparable in quality to that of soybean protein. It has a remarkable nutrient profile with 4-hydroxyisoleucine (4-HI) constituting about 80% of the total content of free amino acids in *Trigonella foenum-graecum* seeds. The seeds also contain trigonelline (*N*-methylnicotinic acid), choline, nicotinic acid, and diosgenin. Essential oil, mucilage, and fixed oil are also major components of the seeds. Fenugreek has been shown to be a feasible source of diosgenin, which occurs in the embryo of the seeds. Fenugreek has been shown to possess antidepressant activity, which has been attributed to the hydroxyisoleucine content. It is also exhibited significant antidiabetic, antihypercholesterolemic, and anti-inflammatory activities. In addition, it possesses immunomodulatory, gastrointestinal protective, antioxidant, and acetylcholinesterase

inhibition (AChEI) activities, and these effects make fenugreek a very valuable functional food.

Pharmacognostical Profile

Botanical Name: *Trigonella foenum-graecum* L.
Synonym: *T. tibetana* (Alef.) Vassilcz.
Family: Meliaceae
Common Names: Fenugreek (E), Fenugrec (F)
African Name: Arabic: helba
Description: An erect herbaceous annual of 10–40 cm, aromatic, and smooth. It has compound leaves, 7–12 cm long. The flowers are whitish or purplish blue blossoming solitarily or in groups of two. The fruits occur as pods of 2–10 cm, long thin and pointed, and contain 10–20 seeds.



Habitat and Distribution: Temperate and Mediterranean regions of Africa. It occurs in Egypt, northern Sudan, Libya, and Tunisia. The plant is cultivated in a small scale in the Jos Plateau of Nigeria and in the Rift Valley of East Africa.

Ethnomedicinal Uses: In north Africa, the seeds are used as an oral antidiabetic. The plant is used as a galactagogue in Sudan.[253] The leaves are used in various folk remedies for the relief of indigestion and general stomach disorders. The seeds are edible and have been used in remedies for rheumatism, chronic cough, enlargement of the spleen and liver, and as a general tonic. Extracts of the seeds are incorporated into several cosmetics claimed to have effect on premature hair loss, and as a skin cleanser.

Constituents: The seeds contain trigonelline (*N*-methylnicotinic acid), choline, nicotinic acid, and diosgenin. Essential oil, mucilage, and fixed oil are also major components of the seeds. Fenugreek has been shown to be a feasible source of diosgenin, which occurs in the embryo of the seeds.[254,255] Heat treatment or fermentation before acid hydrolysis improves the sapogenin yield.[256,257] It contains amino acids and 4-hydroxyisoleucine (4-HI) constitutes about 80% of the total content of free amino acids in *Trigonella foenum-graecum* seeds. Fenugreek seeds also contain a substantial amount of fiber, phospholipids, glycolipids, oleic acid, linolenic acid, linoleic acid, choline, vitamins A, B1, B2, C, nicotinic acid, niacin, and many other functional elements.[258]

Pharmacological Studies: A 2% concentration of the saponin fraction showed *in vitro* spermicidal action against rat and human semen.[259] The alkaloid trigonelline has been shown to counteract the hyperglycemic effect of cortisone given 2 h before or simultaneously. Nicotinic acid and coumarin, which co-occur in the plant, are also hypoglycemic. The compound was moderately effective in alloxan diabetic rats and in human subjects.[260–262]

Fenugreek has been shown to possess antidepressant activity, which has been attributed to the hydroxyisoleucine content. It was found that oral acute administration of 4-HI showed that the dose-dependent reversal in forced-swim induced increased immobility behavior in normal and reserpinized mice in a dose range of 3–30 mg/kg; the SMA scores were not affected by 4-HI in normal or reserpinized mice except for a dose of 30 mg/kg, showing central rather than peripheral mechanism of 4-HI; and a significant increase in the number of 5-HTP (precursor of serotonin) induced head twitches was shown by 4-HI. In conclusion, 4-HI showed antidepressant-like effects in animal models of depression by brain serotonin turnover enhancement.[263] 4-HI has also been found to possess antidyslipidemic and antihyperglycemic activities. It significantly decreased the plasma triglyceride levels by 33% ($P < 0.002$), total cholesterol (TC) by 22% ($P < 0.02$), and free fatty acids by 14%, accompanied by an increase in HDL–C/TC ratio by 39% in the dyslipidemic hamster model.[264]

The plant has immunomodulatory, gastrointestinal protective, antioxidant, and acetylcholinesterase inhibition (AChEI) activities, and these effects make fenugreek a very valuable herbal medicine and dietary supplement.[616] The extract of *Trigonella foenum-graecum* seed is a safe and effective treatment for reducing symptoms of possible androgen deficiency, improves sexual function and increases serum testosterone in healthy middle-aged and older men.[617]

Frankincense: Olibanum

Overview

Frankincense has been known, traded, and used throughout the ages for its exceptional aroma properties, and it is still commonly used in both secular and religious settings to convey a pleasant odor. Frankincense is a gum resin obtained by tapping frankincense trees from the genus *Boswellia* Roxb. ex Colebr. (family Burseraceae). The genus *Boswellia* comprises 19 different species and their phylogenetics and taxonomy are the subject of scientific discussion and research. More than 20 odorants are known to be present in the plant, they include oxygenated monoterpenes, mono- and sesquiterpenes, and a few diterpenoids. Frankincense is used for its antioxidant and anti-inflammatory properties. It has also been employed against ulcerative colitis and cancer.

Pharmacognostical Profile

Botanical Name: *Boswellia sacra* Flueck.

Synonyms: *Boswellia carterii* Birdw. var. *undulato-crenata* Engl.; *Boswellia bhar-dajiana* Birdw.; *Boswellia bhar-dajiana* var. *serrulata* Engl.; *Boswellia undulatocrenata* (Engl.) Engl.

Family: Burseraceae

Common Names: Arabian Frankincense, Bible Frankincense, frankincense, incense, olibanum, olibanum tree

African Names: Somali: mohor (tree), beyo (resin); Swahili: ubani





Description: The frankincense tree may be 1.5–8 m tall, branching from the base or with a distinct trunk, the bark pale brown with some outer flaking, papery layers, and a thick reddish-brown inner resiniferous layer, the young shoots tomentos or rarely glabrous, the resin copious, milky, drying yellowish brown. The leaves are clustered at tips of branches, imparipinnate; the leaflets opposite, 6–8 pairs, oblong, margin crenate, tomentose. The flowers are often in axillary racemes, crowded at the end of branches; racemes up to 10 cm. The calyx is five-lobed. The petals are five, yellow-white, and spreading. Stamens 10. The ovary is surrounded by a fleshy disk. The fruits are apsule, obovoid, broadly pyriform, reddish-brown, glaborous, 8–12 mm, 3–5 angled, opening by 3–5 valves.

Habitat and Distribution: The trees grow in stony soil. They adhere to boulders of rock faces by means of a cushion- or disk-like swelling at the base of the trunk. This swollen base seems to be important in stabilizing the tree and is best developed in trees growing on very steep or exposed rocks but less so, or not at all, in the occasional trees that grow in gravel or in planted specimens. They are found in Somalia and most parts of the Horn of Africa and up to Arabia.

Culinary (Food) Use: It is often chewed like gum, but it is stickier because of its resinous composition.

Ethnomedicinal Uses: Frankincense is used in traditional medicine for the treatment of skin diseases, wound healing, and general inflammation. *Boswellia* has been used in the treatment of acne, amenorrhea, cancer, cystitis, cervical spondylosis and genital infections;

and as an analgesic, diuretic, antiseptic, carminative, expectorant, and sedative. It is also used in religious ceremonies for spirit invocation during serious negotiations and in burial rites. Frankincense resin is eaten as a general restorative tonic and for skin care in the Horn of Africa and parts of the Sahel region. Edible frankincense must be pure for internal consumption, meaning it should be translucent, with no black or brown impurities. It is often light yellow with a (very) slight greenish tint.



Constituents: The oleo-gum-resin frankincense or olibanum is the most important component of the *Boswellia* species and their chemical composition is of immense value in differentiating members of the genus. Olibanum has been reported to be a rich source of monoterpenes, sesquiterpenes, and iridoids, as well as nonvolatile triterpenoic constituents such as ursane, oleanane, and lupine, which are in many cases responsible for some of the observed biological activities. The presence of isoincensole acetate in both *B. sacra* and *B. carteri* has been used as the main diterpenic chemotaxonomic biomarker. Although the diterpene also occurs in *Boswellia serrata* olibanum, the presence of methylchavicol, methyleugenol, and an unidentified oxygenated sesquiterpene distinguishes *B. serrata* olibanum from the two other species. The characteristic chemical compounds of *Boswellia papyrifera* are the diterpenic biomarkers incensole and its oxide and acetate derivatives, *n*-octanol and *n*-octyl acetate. *Boswellia frereana* olibanum is devoid of diterpenes of the incensole family but contains a high amount of many dimers of β-phellandrene. The chemical composition of olibanum, which is demonstrated to be different for each *Boswellia* species allowed the determination of the taxonomic origin of frankincense samples purchased in various markets in East Africa, the Near East, and Yemen. Moreover, terpenic fingerprints allowed the botanical origin of olibanum used in traditional incense mixtures to be identified.[265] The volatile oil derived from the olibanum consists of 75% monoterpenes, sesquiterpenes, monoterpenols, sesquiterpenols, and ketones. It has a good balsamic and sweet fragrance, while the Indian frankincense oil has a very fresh smell. The steam or hydro-distilled frankincense oil does not contain any boswellic acid as these components (triterpenoids) are nonvolatile and too large to come over in the steam distillation process and such claims in proprietary products should be disregarded.

The botanical designation of *B. carterii* as a synonym of *B. sacra* has been challenged based on the detailed chemical profile of both varieties. A transnational team of investigators led by Cole Woolley has evaluated the Somalian (*B. carterii*) and Omani/Yemeni (*B. sacra*) species by chemical analyses to determine if there were any minor or major differences between the two species of frankincense. Components identified with their average percent for *B. sacra* are α-thujene (0.6%), α-pinene (68.2%), camphene (2.1%), sabinene (2.9%), β-pinene (2.0%), myrcene (0.7%), and limonene + β-phellandrene (6.2%). Components identified with their average percent for *B. carterii* are α-thujene (7.9%), α-pinene (37.3%), camphene (0.8%), sabinene (4.9%), β-pinene (1.8%), myrcene (7.3%), and limonene + β-phellandrene (14.4%). Initially, GC–MS analysis did not reveal major statistical differences. However, optical rotation values, *B. sacra* (+30.1°) and *B. carterii* (–13.3°), demonstrated a greater significant difference. Enantiomeric ratio (+)/(–) values of α-pinene for *B. sacra* and *B. carterii* are 8.24 and 0.68, respectively, were also calculated aiding the investigators to conclude that *B. sacra* and *B. carterii* are not synonymous but rather two distinct and individual frankincense species.[266] In a comprehensive, odor-activity-guided approach, both chemoanalytical and human sensory parameters were used to identify odor active constituents of the volatile fraction of *B. sacra*, to include as the key odorants α-pinene, β-myrcene, linalool, *p*-cresol, and two unidentified sesquiterpenoids. A total of 23 odorants were detected and analyzed by gas chromatography–olfactometry and heart-cut two-dimensional gas chromatography–mass spectrometry/olfactometry. The majority of the identified odorant compounds were oxygenated monoterpenes, along with some relevant mono- and sesquiterpenes and only one diterpenoid substance.[267]

Pharmacological Studies: The volatile oils from several species of *Boswellia* have been evaluated for their antimicrobial activity. The antimicrobial activity (minimum inhibition concentration assay) ranges of the oils were 4–16 mg/mL (*Staphylococcus aureus*); 1.5–8.3 mg/mL (*Bacillus cereus*); 4.0–12.0 mg/mL (*Escherichia coli*); 2.0–12.8 mg/mL (*Proteus vulgaris*), and 5.3–12.0 mg/mL (*Candida albicans*).[268] The gum exudate of some *Boswellia* species contain four major triterpenic acids known as boswellic acids (BAs), that is, β-boswellic acid (BA), 3-*O*-α-acetyl-β-boswellic acid (ABA), 11-keto-β-boswellic acid (KBA), and 3-*O*-α-acetyl-11-keto-β-boswellic acid (AKBA). The boswellic acid acylates, including their epimers, were synthesized and screened against a panel of human cancer cell lines. They exhibited a range of cytotoxicity against various human cancer cell lines, thereby leading to the development of a possible structure–activity relationship (SAR). One of the identified lead compounds was found to be an inhibitor of the NF-κB and STAT proteins, and it is currently being investigated for development as an anticancer agent.[269]

The anti-inflammatory activity of boswellic acids has been shown to be probably due to the direct inhibition of lipopolysaccharide (LPS) functionality and LPS-induced cellular responses. In pull-down experiments, LPS could be precipitated using an immobilized BA, implying direct molecular interactions. Binding of BAs to LPS leads to an inhibition of LPS activity, which was observed *in vitro* using a modified limulus amoebocyte lysate assay. Analysis of different BAs revealed clear structure–activity relationships with the classical β-BA as the most potent derivative (IC_{50} = 1.8 μM).[270]

Boswellia has been used clinically for the management of ulcerative colitis; however, the second European evidence-based consensus on the diagnosis and management of ulcerative colitis found the clinical evidence insufficient to approve the use of BSE and Bas in the treatment of this serious disease.[271] It has also been used for the treatment of asthma, depression, and osteoarthritis.

Commerce: Frankincense occurs in various forms in commerce. The crude olibalum is sold in markets in Somalia, Djibuti, Yemen, and neighboring countries in the Horn of Africa and Middle East. The essential oils are exported for the perfumery industry and for use in aromatherapy. The product from Sudan is mostly *Boswellia papyrifera* and the Indian frankincense is *Boswellia serrata.* The edible frankincense, which is translucent, often light yellow with a slight greenish tint and with no black or brown impurities, is consumed in most parts of the Horn of Africa. It is often chewed like gum, but it is stickier because it is a resin. It is the frankincense produced along the northern coast of Somalia from which the Roman Catholic Church draws its supplies.

Agriculture: The propagation of *Boswellia sacra* trees is difficult although the plant can adapt to extremely harsh environments. They are considered unusual for their ability to grow in environments so unforgiving that they sometimes grow directly out of solid rock. The trees start producing resin when they are about 8–10 years old. Tapping is done 2–3 times a year with the final taps producing the best tears due to their higher aromatic terpene, sesquiterpene, and diterpene content. In commerce, the more opaque resins are considered to be the best quality. According to recent surveys, frankincense tree populations are declining, partly due to overexploitation. Heavily tapped trees have been found to produce seeds that germinate at only 16% while seeds of trees that had not been tapped germinate at more than 80%. It has been further observed that bush burning, grazing, and attacks by the longhorn beetle have reduced the tree population.[596]

Formulation and Dosage Form: The only known formulations are gels for external use. The herb is used alone or in a mixture with other wound-healing agents.

Garden Egg: African Eggplant

Overview

The African garden egg (originally known as the scarlet and gboma eggplants but the name "eggplant" now refers to an Asian crop) exists in different forms, which were in the past described as a distinct species. Recent studies have shown that all these plants are highly interfertile, and better treated as one species, having arisen by domestication from a single wild progenitor: *Solanum anguivi*. Four main groups of cultivars of *Solanum aethiopicum*, with different uses, are now recognized: the *Shum*, *Kumba*, *Gilo*, and *Aculeatum* groups. The first three are native to Africa and are used as food and medicine; the fourth is an ornamental plant of European origin and has inedible fruits. The term "garden egg" or "African egg" includes the related species "gboma" (*S. macrocarpon*). The African garden egg is among the most appealing vegetables ever, with a very rich color variety. Among Africa's overall garden egg diversity, it is possible to find fruits in white, cream, yellow, green, lime, orange, pink, red, plum, burgundy, lavender, violet, purple, or dusky black. Many are striped and even multicolored. All possess a glossy skin that tends to shimmer in the sunlight. Beyond being egg-shaped, they can also be round, flat, ribbed, and pumpkin-like. As food, they can be chewed, sliced, or pureed into juice and eaten fresh like tomatoes. Depending on the type, some are sweet, others are tart and bitter. The nutrient value of *Solanum aethiopicum* fruits is comparable with that of eggplant *Solanum melongena* (brinjal or aubergine). Other constituents of the fruits include the phytosterols, betulin and sterolin (sitosterol glucoside), flavonoids, and terpenes. The

characteristic bitter taste of some of the cultivars has been attributed to furostanol glycosides. Several sesquiterpenoids, the antifungal agents lubimin and epilubimin, have been found in the roots. Garden egg has anti-inflammatory and antiulcer properties. The plant has also been found to possess antifungal, antioxidant, and hepatoprotective activities.

Pharmacognostical Profile

Botanical Name: *Solanum aethiopicum* L.

Synonyms: *Solanum gilo* Raddi; *Solanum olivare* Paill. & Bois.; *Solanum pierreanum* Pailleux & Bois.

Related Species: *Solanum macrocarpon* L.

Family: Solanaceae (nightshade family) section Oliganthes

Common Names: African eggplant, garden egg, scarlet eggplant, bitter tomato, mock tomato, Ethiopian eggplant, African bitter pea-aubergine, wild pea-aubergine, wild African aubergine, tomato-fruited eggplant, Ethiopian nightshade

African Names: Igbo (Nigeria): anara, afufa; Yoruba: igbagba, ikan; Ghana: agbitsa; Sudan: guta, quta; Swahili: ngilo; Uganda: nakati, nakasuga; Burkina Faso: banse, goyo, kumba; Senegal: djackattou, jaxatu, njakatu; Rwanda: intobo, umucucu; Afrikaans (Namibia): bitterappel, grysbitterappel; Afrikaans (South Africa): bitterappel, gifappel, grysbitterappel; Kikuyu (East Africa): mutongu; Boran (Kenya): idi-gaga; Digo (Kenya): mtunguza-koma; Gabbra (Kenya): (h) iddi-loonni; Chagga: nduo; Ilwana (Kenya): muhidi; Kamba (Kenya): mukondu; Damara/Nama (Namibia): soropes; Herero (Namibia): omundumburiri, omundumbwiriri, omutimburiri; Himba (Namibia): omundumbwiriri; Khoekhoegowab (Namibia): soropees; Ki-arusha: indulele; Kibende: ntufululu; Kifiome: nangali; Kihene: ndula; Kijita: mtobolo; Kikerewe: mtobotobo

Description: *Solanum aethiopicum* is a woody deciduous annual or occasionally perennial herb, up to 200 cm tall, often much-branched; the root system extending both vertically and laterally; branches and leaves with or without prickles and stellate hairs. The leaves are alternate, simple; stipules absent; the petiole up to 11 cm long; the blade broadly ovate, (6–) 12–30 cm × (4–) 7–21 cm, obtuse or cordate at base, acute to obtuse at apex, slightly to deeply lobed at margin, pinnately veined; the upper leaves smaller, narrower, less lobed and often subopposite.[4] In the vegetative stage, a plant of the *Gilo* group looks like a common Asian eggplant (i.e., *Solanum melongena*). Features distinguishing it from the other species are the small, white, star-shaped flowers. In addition, the calyces are never long and the inflorescence has short (1 cm) rachis. The fruits are 3–6 cm in diameter, varying in shape from ellipsoid to almost round. They contain 2–6 locules and are normally firmly attached to thick fruit stalks that turn downward. The flowers are pollinated by large bees.[272] The species exists in different forms, which were in the past described as about 20 species. Recent studies have shown that all these plants are highly interfertile, and better treated as one species, having arisen by domestication from a single wild progenitor: *Solanum anguivi*. Four main groups of cultivars of *Solanum aethiopicum*, with different uses, are now recognized: the *Shum*, *Kumba*, *Gilo*, and *Aculeatum* groups. The first three are native to Africa and are used as food and medicine; the fourth is of European origin and has inedible fruits.[4]

Habitat and Distribution: *Solanum aethiopicum* occurs in virtually all of sub-Saharan Africa, but is less well known in (or probably absent from) South Africa and Madagascar. It is believed to be a domesticated cultivar from the wild *Solanum anguivi* Lam., via the semi-domesticated *Solanum distichum* Schumach. & Thonn. The two species occur throughout

tropical Africa, *Solanum anguivi* in disturbed vegetation and *Solanum distichum* in gardens. *Solanum aethiopicum* is grown throughout tropical Africa and South America (mainly Brazil), and occasionally elsewhere, for example, in southernmost France and Italy. It is one of the leading vegetables in tropical Africa. In the humid zone of West Africa, it is mainly grown for its immature fruit (garden egg), in the savanna area frequently for both its leaves and immature fruits (often called "djakattou"), and in East Africa, especially Uganda, mainly as a leaf vegetable (called "nakati").[4]

Culinary (Food) Use: The immature fruits of *Solanum aethiopicum* are usually eaten raw and sometimes cooked as vegetables in stews. The leaves and shoots are also used as a cooked vegetable. The Igbo people of south-eastern Nigeria traditionally welcome visitors into the family house by offering the fruits either alone or with seeds of *Cola nitida* and *Aframomum melegueta*.

Ethnomedicinal Uses: Fruits of the bitter cultivars and roots are used in traditional medicine in many African countries. They have been used for the treatment of diabetes, hypertension, and stomach complaints, as a carminative and sedative, and for colic. The leaf juice has been used as a sedative to treat uterine complaints; an alcoholic extract of leaves as a sedative, an antiemetic, and to treat tetanus after abortion; and crushed and macerated fruits as an enema.

Constituents: The nutrient value of *Solanum aethiopicum* fruits is comparable with that of eggplant. A 100 g edible portion yields: water 90.6 g, energy 135 kJ (32 kcal), protein 1.5 g, fat 0.1 g, carbohydrate 7.2 g, fiber 2.0 g, Ca 28 mg, P 47 mg, Fe 1.5 mg, β-carotene 0.35 mg, thiamine 0.07 mg, riboflavin 0.06 mg, niacin 0.8 mg, and ascorbic acid 8 mg. The composition of fresh leaves per 100 g edible portion is water 82.1 g, energy 215 kJ (51 kcal), protein 4.8 g, fat 0.3 g, carbohydrate 10.3 g, fiber 2.4 g, Ca 523 mg, P 94 mg, Fe 6.0 mg, β-carotene 6.40 mg, thiamine 0.23 mg, riboflavin 0.44 mg, niacin 1.8 mg, and ascorbic acid 67 mg. Other constituents of the fruits include the phytosterols, betulin and sterolin (sitosterol glucoside), flavonoids, and terpenes. Steroidal glycosides, named aethiosides A, B, and C, possessing a homocholestane skeleton with an aromatized ring E, also occur in *Solanum aethiopicum*. The characteristic bitter taste has been attributed to furostanol glycosides.

Several sesquiterpenoids, the antifungal agents lubimin and epilubimin, have been found in the roots. The leaves contain oxalate and alkaloids, for example, solasodine, which has glycocorticoid effects. Their concentration is reduced by cooking.[4]

Pharmacological Studies: *Solanum aethiopicum* has been evaluated mainly for its nutritional value. The bitter cultivars with steroidal alkaloids exhibit the pharmacological activity associated with that class of compounds. The anti-inflammatory activity of the fruits has been evaluated using the egg albumin-induced rat paw edema model. Extracts of garden egg significantly ($P < 0.05$) reduced the fresh egg albumin-induced rat paw edema and also significantly ($P < 0.05$) reduced the granuloma tissue formation in the treated groups when compared to the control.[273] In a comparative study to determine the effect of African garden egg, *S. aethiopicum* against gastric ulcers, methanol extract of the fruit was administered orally at dose levels of 100, 200, and 400 mg/kg and 100 mg/kg of ranitidine to rats with experimentally induced ulcers. For the indomethacin and aspirin models, ulcerogenic agents (indomethacin 50 mg/kg and aspirin 200 mg/kg) were given 30 min after extract treatments and animals sacrificed 8 h later. The acidified ethanol model (ethanol 60% + 0.1 mol/L HCl) was given 1 h after extract treatment and animals sacrificed 1 h later. The ulcer index was checked and analyzed with appropriate statistical tools. The extract of *S. aethiopicum* showed a positive effect on all the models used. It produced higher ulcer inhibition than ranitidine in the indomethacin and acid-ethanol models. All the antiulcer

effects of the extract at different doses were dose dependent but only in the indomethacin model did it produce statistically significant ($P < 0.05$) ulcer reduction in all doses compared to the control. Garden egg therefore has a high potential as a cheap and available source of natural antiulcer remedy.[274]

The plant has also been found to possess antifungal, antioxidant, and hepatoprotective activities.[275]

Toxicity: Some members of the Solanaceae family contain steroidal alkaloids and some of them are known to be toxic. The rule of the thumb is to avoid very bitter cultivars. The related *Solanum macrocapon* has been shown to contain antinutrient principles (phytate and cyanide) in the leaves. The aqueous infusion of the fresh leaves of *S. macrocapon* caused hemolysis of human erythrocytes *in vitro*. The blood type-SS were more susceptible to hemolysis than either AA[276] and AS. It was therefore concluded that the various conventional food processing techniques will significantly reduce the nutrient and antinutrient content of eggplant leaves, without adversely affecting the estimated Zn bioavailability to a critical level. Furthermore, the leaf infusion had high hemolytic effect on genotype-SS *in vitro*.[277]

Agriculture: The African garden egg is cultivated extensively throughout tropical Africa. It is an easily grown plant, which thrives well in most soils. Nonetheless, it does best in soils of high fertility, especially those high in nitrogen and phosphorus. Sandy loam to friable clay soils with a pH range of 5.5–6.8 have been declared particularly suitable. It has been shown that simultaneous planting of cowpea and scarlet eggplant produced 90%–99% of the fruit yield of sole scarlet eggplant, while planting cowpea 2 and 4 weeks ahead produced 65%–80% and 58%–60% of sole crop yield, respectively. Competition between component crops was however most favorable for both cultivars of cowpea when planted 2 weeks ahead of scarlet eggplant. Planting cowpea 2 weeks ahead of the main crop also produced the highest LER most likely due to more efficient utilization of sunlight, water, and soil nutrients. Simultaneously planting cowpea and transplanting scarlet eggplant was therefore recommended for such additive intercropping system, aimed at full yield of scarlet eggplant with additional cowpea for food, income, or fodder.[278]

Three of the four cultivar groups that are recognized within *Solanum aethiopicum*, are important for Africa:

- *Gilo group*. The fruits are consumed. This is the most important cultivar group, which includes cultivars with smooth fruits that are popular in West and East Africa, and cultivars with more or less strongly ribbed fruits. Mature leaves covered with stellate hairs, generally not prickly; fruit subglobose to ellipsoid, 2.5–12 cm long. Depending on the location, preference is given to cultivars with pure white, creamy white, pale green, dark green, brown, or purple fruits, or cultivars with fruits striped in two or more colors. Cultivars of *Gilo* group are grown throughout tropical Africa in the more humid areas.
- *Shum group*. Only the leaf is used (the fruits being too bitter). This has fairly small, subspherical fruits and small glabrous leaves. It is distributed throughout Central Africa, as well as in western equatorial Africa, Nigeria, Benin, Togo, and Ghana.
- *Kumba group*. This has much-lobed glabrous fruits that are pumpkin-shaped and only slightly bitter. When ripe, they are light green to red-orange—very ornamental and unusual looking with lots of bumps. Both leaves and fruits are eaten. The species is restricted to the sub-Sahelian region from Senegal, Mali, Bukina Faso, Niger to northern Nigeria and parts of Cameroon.

Members of the plant family Solanaceae often contain toxic steroidal alkaloids; therefore, horticultural breeding has to be carefully done in order not to introduce toxic cultivars by mistake.

Garlic

Overview

Garlic is valued for its remarkable antioxidant, anti-inflammatory, and general restorative effect on health. The plant is indigenous to Asia but has been introduced to Africa, where it is cultivated in many parts of the continent and is a vital ingredient in many traditional remedies. Early records include recipes from Mesopotamian cuneiform tablets and medical remedies detailed in the Egyptian Ebers Papyrus. Garlic produces a volatile oil, which consists of sulfur-containing compounds, including *S*-allyl-2-propenthiosulfinate (allicin), methylallyltrisulfide (MATS), diallydisulfide, diallyltrisulfide, diallyltetrasulfide, allylpropyldisulfide, ajoene (4,5,9-trithiododeca-1,6,11-triene 9-oxide), 2-vinyl-4*H*-1,3-dithiin, and allin. Garlic has a characteristic pungent aroma and flavor, which are disagreeable to many people. The characteristic aroma and flavor of crushed fresh garlic are due to the presence of relatively simple sulfur compounds. Additional sulfur compounds are generated during cooking or processing, which can modify not only the aroma and flavor but also potential health effects. The many forms in which garlic is ingested, and their corresponding diverse chemical profiles, make the study of garlic-related health benefits an interesting and challenging field. It has been shown by several clinical studies to be beneficial in the management of various neurodegenerative diseases and metabolic dysfunction.

Pharmacognostical Profile

Botanical Name: *Allium sativum* L.

Synonyms: *Porrum sativum* (L.) Rchb.; *Porrum ophioscorodon* (Link) Rchb.; *Allium pekinense* Prokh.; *Porrum ophioscorodon* Link.; *Allium longicuspis* Regel; *Allium controversum* Schrad. ex Willd.

Family: Amaryllidaceae

Common Names: Garlic, ail commun (Fr.)

African Names: Hausa: tafanuwa; Igbo: ayo-ishi; Swahili: kitunguu-sumu; Yoruba: ayu

Description: Garlic is a herbaceous plant. The drug occurs as a bulb of fleshy scale leaves on the lower part of the stem; each bulb consists of a number of bulbets or "cloves" rested on a common bulb base and covered with membranous bracts. It has a very strong and disagreeable odor that is noticeable in the breath and a strongly pungent and persistent taste—both the odor and taste linger for several days following the ingestion of the plant. Garlic includes two basic varieties: hardneck and softneck. Hardneck garlics, which include *A. sativum* var. *ophioscorodon* and *A. sativum* var. *pekinense*, are characterized by hard, woody central stalks that extend down to the basal plate at the bottom of the bulb.



Habitat and Distribution: It is indigenous to Asia but has been introduced to Africa, where it is cultivated in many parts of the continent.

Ethnomedicinal Uses: It is used for the treatment of respiratory infections and as an anthelmintic. It is applied externally in northern Nigeria for the treatment of skin diseases. In parts of Chad, the fresh bulbs are used in the preparation of tonics for diabetes and hypertension.

Constituents: Garlic yields 0.1%–0.3% of a volatile oil consisting of sulfur-containing compounds, including *S*-allyl-2-propenthiosulfinate (allicin), MATS, diallydisulfide, diallytrisulfide, diallytetrasulfide, allylpropyldisulfide, ajoene (4,5,9-trithiododeca-1,6,11-triene 9-oxide), 2-vinyl-4*H*-1,3-dithiin, and allin, which yields allicin on enzymatic hydrolysis.[279,280] The oil also contains the terpenes citral, geraniol, linalool, and α- and β-phellandrene, and various enzymes, including allinase, vitamins of the B group, flavonoids, and several minerals. Studies have shown that aged garlic has a chemical profile that is distinct from the fresh materials and whenever possible aged garlic should be used.

Pharmacological Studies: It has been established that extracts of garlic possess demonstrable antiatheromatous properties. In feeding experiments with rabbits, the animals given garlic had very less marked increase in blood cholesterol than those given the same diet but without garlic.[281] The oil extracted from garlic prevents fat-induced hypercholesterolemia[282] and sucrose-induced hyperlipidemia,[283] and enhances fibrinolytic activity.[284] *In vitro* studies showed that garlic inhibits platelet aggregation.[285] It has also been observed that conversion of labeled arachidonate (AA) in garlic oil-treated platelets is impaired compared to the control in the elaboration of platelet cyclooxygenase and lipoxygenase products.[286] Aqueous extract of garlic inhibited aggregation induced by ADP, collagen, arachidonate, epinephrine, and calcium ionophore A23187 in a dose-dependent manner.[287] It has demonstrable antioxidant properties.[288] These effects have indirect relationship to the use of garlic in the treatment of hypertension. The drug has been shown in five consecutive cases of hypertension to reduce blood pressure to satisfactory levels.[289]

Other pharmacological activities include pronounced hypoglycemic activity in animals and humans[290]; the drug also contains substances with hyperglycemic activity.[291] In rabbits, the maximum fall in blood sugar level given a glucose loading dose with garlic

juice was 12% compared with 20% for those treated with tolbutamide and 2% for those given a water control.[292] It has also been observed that in a group of mice injected with cancer cells incubated with garlic extract, no deaths occurred for up to 6 months while mice injected with untreated cancer cells died within 16 days.[293] Garlic extracts and more specifically allicin have been shown to be active *in vitro* against *Candida albicans*, *Trichomonas* spp., *Staphylococcus aureus*, *Salmonella typhi* and *paratyphi*, *Shigella dysenteriae*, *Vibrio cholerae*, and *Escherichia coli*.[294,295] It was active against some mutidrug-resistant bacteria *in vitro*.[296] One of the active metabolites of garlic, allicin, possessed significant antifungal activity *in vitro* against *Candida*, *Cryptococcus*, *Trichophyton*, *Epidermophyton*, and *Microsporum* species.

Garlic shows a general tonic effect even at very low doses due to the stimulation of hypophyseal function and this property has been exploited in relation to Seyle's stress syndrome. The beneficial effects of garlic extract injections upon lindane-induced damages in testes, brain, and thyroid function have been evaluated experimentally and it was found that 300 mg fresh garlic/kg/day counteracted the damage to this organs caused by lindane.[297]

Clinical Applications: In clinical practice, garlic is used for long-term treatment of hypertension,[298] degenerative heart disease, and atherosclerosis.[299] The medication should be given for an extended period, at least 3 months, to achieve the desired results. A social problem with garlic medication is the persistent pungent smell. Attempts to present garlic in dosage forms that mask the odor have not been successful since the disagreeable odor comes about when constituents containing sulfur are eliminated via the skin and respiratory passages. It has also been observed that reduction of the smell by encapsulation and adsorption to charcoal invariably leads to reduced activity.[300] The dosage is determined relative to the severity of the condition being treated and lies between 10 and 25 g of the whole drug or 2 and 8 mL of the syrup. Garlic is available in health food shops in the following forms: garlic bulbs, tincture, capsules, and garlic juice.

Garlic is also used as expectorant, diaphoretic, disinfectant, and diuretic. Extracts of the plant, as well as the constituents diallyldisulfides and diallyltrisulfides are active against the *Culex* mosquito. The isolates were larvicidal at 5 ppm.[301] According to some Chinese doctors, application of thin slices of garlic bulb aided the healing during repair of perforations of the eardrum in 17 of 18 patients (Y. B. Rong, 1989, pers. comm.).

Although garlic and onion are frequently recommended for degenerative heart disease, an analysis of the relationship of garlic and onion consumption to mortality from ischemic heart disease in 27 countries raised doubts about the protective effect of garlic.[302] Several clinical trials, however, have demonstrated the beneficial effects of garlic as a dietary supplement.

Toxicity: Garlic is not known to cause any serious toxicity when consumed in moderate quantities. Allicin yields a degradation product that often causes severe halitosis following the ingestion of large quantities of garlic.[303] Contact dermatitis to garlic has been reported.[304] There is a case report of prolonged inhalation of garlic dust by a food industry worker that resulted in the development of a severe asthmatic reaction with subsequent cross-allergenicity to other plants of the families Liliaceae and Amaryllidaceae.[305] Garlic medication is contraindicated in ambulatory patients taking anticoagulant drugs due to possible prolongation of bleeding time. According to *Martindale: The Extra Pharmacopoeia*, the administration of preparations of garlic to children is dangerous and fatalities have been recorded.

Of serious clinical consequence is the high incidence of confusing plants containing colchicine with wild garlic, which cause potentially fatal intoxications. A reported case

showed that the patient initially presented with mild gastrointestinal symptoms, but progressed rapidly to agranulocytosis, paraparesis, and delirium before the causative agent was identified.[306] Laboratory tests revealed rhabdomyolysis, coagulopathy, alteration of liver tests, and prerenal azotemia. Subsequent botanical examination confirmed the incriminated plant (*Colchicum autumnale*). Serum and urine analysis confirmed the presence of colchicine.

Ginger

Overview

Ginger is the rhizome of the tropical plant *Zingiber officinale* Roscoe. Ginger has a distinctive odor and aromatic, pungent, and agreeable taste. Two varieties are known in commerce, the mild tasting and often peeled West Indian variety called "Jamaican ginger" and the more pungent and usually unpeeled variety called "Nigerian" or "African ginger." Ginger yields a volatile oil, which consists mainly of camphene, citral, cineol, linalool, zingiberene, bisbolene, zingiberol, zingiberenol, and methylheptenone. The plant also yields pungent phenolic principles known as gingerols and shogaols. The anti-inflammatory, antioxidant, and antinausea properties of ginger has been the subject of many laboratory studies. Other biological activities of ginger and its constituents that have been validated by laboratory studies include antihepatotoxic, antiviral, antiarthritic, and chemopreventative activities and the treatment of morphine dependence. In human clinical studies, ginger has been shown to suppress gastric secretion and reduces vomiting. It was effective in reducing the pain and immobility caused by osteoarthritis. Capsules containing 940 mg of the dried rhizome were found to be superior to the antihistamine dimenhydrinate (100 mg) in preventing motion sickness. Proprietary products containing ginger are available in China and Japan for the treatment of elevated blood pressure and degenerative heart diseases. In some formulations, it is claimed that the steamed ginger has better therapeutic outcome than the fresh rhizome.

Pharmacognostical Profile

Botanical Name: *Zingiber officinale* Roscoe

Synonyms: *Amomum zingiber* L.; *Zingiber blancoi* Mask.; *Z. majus* Rumph.; *Curcuma longifolia* Wall; *Zingiber cholmondeleyi* (F.M.Bailey) K.Schum.; *Zingiber sichuanense* Z.Y.Zhu, S.L.Zhang & S.X.Chen.

Family: Zingiberaceae

Common Names: Ginger, gingembre (Fr.)

African Names: Arabic: zanjabeel; Hausa: sankanjabir, citaraho; Igbo: jinja; Swahili: tangawizi; Yoruba: ata-Ie, jinja

Description: Ginger is the rhizome of the tropical plant *Zingiber officinale* Roscoe. Two varieties are known, the mild tasting and often peeled West Indian variety called "Jamaican ginger" and the very pungent and usually unpeeled variety called "Nigerian" or "African ginger." The plant is a perennial with green-purple flowers that occur in terminal spikes and resemble orchids. It has a distinctive odor and aromatic, pungent, and agreeable taste.

Habitat and Distribution: The natural habitat is the well-drained savannah and semitropics. The plant is, however, cultivated in nearly all parts of the continent. A variety

similar to the West Indian mild-tasting cultivar has been successfully developed at the Root Crop Research Institute of Nigeria, Umudike-Umuahia.

Culinary (Food) Use: Ginger is used globally as a spice in many cuisines. Young ginger rhizomes are juicy and fleshy with a very mild taste. They can be used as teas. It can be made into a refreshing drink either alone or with other plants such as bissap, pineapple, orange, and lemon. Ginger can be made into candy, or ginger wine, or added in cereals as ginger flakes.

Medicinal Uses: Ginger is used extensively as a culinary plant and in African folk medicine as a carminative, diuretic, and antiemetic. In China and Japan, it is one of the commonest ingredients in the preparation of remedies for gastrointestinal distress, liver diseases, and hypertension.

Constituents: Ginger yields 1%–3% volatile oil, which consists mainly of camphene, citral, cineol, linalool, zingiberene, bisbolene, zingiberol, zingiberenol, and methylheptenone. The plant also yields pungent phenolic principles known as gingerols and shogaols. The shogaols, which are more pungent than the gingerols, are believed to be formed by dehydration and the degradation of the latter during drying and extraction.[307]

Pharmacological Studies: The methanolic extracts of the rhizome of ginger show strong positive inotropic effects on guinea pig isolated left atria in a dose-dependent manner. The cardiotonic properties are associated with the presence of gingerols.[308] Two of the constituents, (6)-gingerol and (6)-shogaol, have been shown to be cardiodepressant at low doses and cardiotonic at high doses.[309] Both compounds inhibited spontaneous motor activity, produced antipyretic and analgesic effects, and prolonged hexobarbital-induced sleep in laboratory animals.

The compounds also possess strong antitussive effects that were found comparable to those of dihydrocodiene (Y. B. Rong, 1991, pers. comm.). (6)-Gingerol and (6)-shogaol were also shown to suppress gastric contractions. It is noteworthy that (6)-shogaol inhibited intestinal motility when administered intravenously but accentuated gastrointestinal motility after oral administration.[3] Gingerols and shogaols have been shown to have demonstrable hypotensive effects.[310] 6-Shogaol induced pressor responses in the blood pressure of rats at a dose of 0.5 mg/kg (i.v.), which was markedly reduced by spinal destruction to the sacral cord level (unlike norepinephrine). The pressor response induced by (6)-shogaol was also reduced by hexamethonium (10 mg/kg, i.v.) and phentolamine (10 ng/kg, i.v.) and similar agents when the spinal cord was destroyed to the thoracic cord level; but the pressor response remained unaffected by these blockers in rats whose spinal cords were destroyed to the sacral cord level.[311] When (6)-shogaol (0.5 mg/kg, i.v.) was administered to rats, blood pressure showed a triphasic response, which consisted of a rapid fall, followed by a rise and a delayed fall. It was also observed that the rapid fall, which followed immediately after the injection of the compound, disappeared with the use of atropine and vagotomy, whereas the sequential marked rise was not affected by α-adrenoceptor blockade and calcium antagonists and ganglion blockade; only a combination of the three inhibited this pressor response. The repeated injections of (6)-shogaol caused a tachyphylaxis in mesenteric and tail vascular beds and a slight tachyphylaxis in rat hindquarters.

The anti-inflammatory activity of ginger has been evaluated by many investigators.[312] In several preclinical studies with experimental animals, ginger and some of its compounds were effective in preventing chemically induced arthritis.[313] Ginger has also been evaluated against a rheumatoid arthritis (RA) model. A hydroalcoholic extract of ginger was found to be effective in ameliorating the collagen-induced inflammatory process and arthritis in rats. Administering ginger extract intraperitoneally for 26 consecutive days

ameliorated the clinical scores, disease incidence, joint temperature, swelling, and cartilage destruction. Assessment of the biochemical indexes of the inflammation process showed that the ginger administered cohorts had a reduction in the serum levels of IL-1b, IL-2, IL-6, TNF-a, and anti-CII antibodies in the serum. The extract (200 mg/kg/day) was observed to be better than 2 mg/kg/day of indomethacin used as a positive control. It has been suggested that cumulatively, these results clearly indicate that the extract of ginger was a good alternative to nonsteroidal anti-inflammatory drugs for RA and that it mediates its protective effects by decreasing inflammation and modulating the proinflammatory cytokines.[314]

Laboratory studies in animals have shown that 6-gingerol possesses significant anti-inflammatory properties.[315] It inhibits NO production, reduces iNOS in LPS-stimulated J774.1 cells, suppresses the peroxynitrite-induced oxidation of dichlorodihydrofluorescein, inhibits single-strand breaks in supercoiled pTZ 18U plasmid, and inhibits the formation of 3-nitrotyrosine in bovine serum albumin and J774.1 cells.[316] A cyclic sesquiterpene, zerumbone isolated from the related species *Zingiber zerumbet* Smith was investigated using carrageenan-induced paw edema and cotton pellet-induced granuloma tissue formation test in mice. It was demonstrated that intraperitoneal administration of zerumbone at a dose of 5, 10, 50, and 100 mg/kg produced significant dose-dependent inhibition of paw edema induced by carrageenan. It was also demonstrated that the compound at similar doses significantly suppressed granulomatous tissue formation in cotton pellet-induced granuloma test.[317] Ginger and its major constituents have demonstrated remarkable chemoprotective properties against various types of cancer. It has been shown that antiproliferative effect of steamed ginger at 120°C for 4 h was approximately 1.5- and 2-fold higher than that of dried and fresh ginger, respectively. Twenty-two components were characterized in the steamed ginger. The decreased concentration of gingerols and increased levels of shogaols contributed to the improved anticancer potential of the steamed ginger.[318]

Other biological activities of ginger and its constituents that have been validated by laboratory studies include antihepatotoxic and antiviral activities and the treatment of morphine dependence.

Clinical Properties: It has been shown in human studies that ginger suppresses gastric secretion and reduces vomiting.[319] Capsules containing 940 mg of the dried rhizome were shown to be superior to the antihistamine dimenhydrinate (100 mg) in preventing motion sickness.[320] Proprietary products containing ginger are available in China and Japan for the treatment of elevated blood pressure and degenerative heart diseases. The efficacy of ginger in reducing the pain in patients with OA (osteoarthritis) has been evaluated in a randomized, double-blind, placebo-controlled, multicenter, parallel-group, 6-week study period. At the end of the study, when compared to the placebo cohorts, administering ginger capsule (255 mg of extract drawn from 2500 to 4000 mg of dried ginger rhizomes) twice daily, morning and evening, reduced the pain on standing and after walking 50 feet.[321] Another randomized double-blind, placebo-controlled, crossover study of 6 months duration confirmed the activity of ginger in the management of OA. It was observed that administration of ginger extract (250 mg per capsule, q.i.d.), was effective as placebo during the first 3 months of the study but at the end of 6 months, 3 months after crossover, ginger showed a significant superiority over the placebo group in reducing the pain and discomfort associated with OA.[322]

Toxicity: No serious toxicity has been reported from using dry ginger, the oil, or any of its active constituents. Large doses have been reported as capable of causing CNS depression and cardiac arrhythmias.[1]

Globe Artichoke: Cardoon

Overview

Globe artichoke (*Cynara cardunculus*) is a favorite salad ingredient in the Mediterranean regions of Africa. It is also used in the preparation of cheese. It is cultivated in North Africa with a good and stable yield for the leaves used as vegetables, stem as sources of lignocellulosic biomass for energy, while its seeds are a source of oil (both edible and for producing biodiesel). Repeated cropping improves the yield of both the fresh and the dry weight of the harvested leaves and the active constituents, such as carbohydrate, flavonoid, polyphenol, and chlorogenic acid content. It has been shown that as the number of harvests increased (up to three harvests), the values of these parameters also increased in both seasons. Globe artichoke has potential benefit in the treatment of diabetes and obesity, and as an antioxidant.

Pharmacognostical Profile

Botanical Name: *Cynara cardunculus* subsp. *flavescens* Wiklund.
Synonym: *C. cardunculus* L. spp. *scolymus* Hay.
Family: Compositae
Common Names: Globe artichoke, leaf artichoke, artichaut (Fr.)
African Names: Arabic: kharsuf
Description: *Cynara* is a small herbaceous and thorny plant, ca. 1.5 m in height. The leaves are alternate, deeply dentate, almost pinnatified whitish capitulum of tall purple flowers that are in turn subtended by thick and imbricate bracts. The crude drug consists of the fresh, thickened lower parts of the involucre bracts and the receptacle of thistle-like flowers of the plant.[597] They are usually greenish or purplish, with the intact bract showing involucre scales enlarged at the base with a short, sharp spine arising from the notched apex. It has a soft and enlarged receptacle that forms a cushion-like mass. The plant has a faint characteristic odor and a peculiar taste.
Habitat and Distribution: Artichoke is a Mediterranean plant. It is cultivated in North Africa and in some subtropical regions of the continent.
Culinary (Food) Use: The cardoon plant is a prominent ingredient in worldwide and Mediterranean cuisine, especially in salads and/or soup dishes. The flowers are also used in for cheese manufacturing.
Ethnomedicinal Uses: The African pharmacopeia listed the plant for the treatment of liver dysfunction, and as a diuretic and antiatherosclerotic. It imparts a sweet taste to food and can be used as sugar substitute for diabetics. It also possesses antimicrobial, choleretic, cholagogue, and diuretic properties.[323]
Constituents: It contains chlorogenic acids, cyanarin, and sesquiterpenes.[230] The plant also contains a mixture of polyphenolic compounds, proteins, and inulin. The leaves contain cyanarin and silymarin.[324]
Pharmacological Studies: Constituents of *Cynara* have been shown to improve the function of both the liver and gall bladder, stimulating the secretion of digestive juices secretion, particularly bile, and lower blood cholesterol levels. It has also been used in cosmetic formulations.[325] Because of its high phenolic content, it has immense potential in the treatment of inflammatory diseases.

Gnetum: Eru, Okazi

Overview

Gnetum is highly valued vegetable that grows wild in West and Central Africa but is occasionally cultivated in homesteads. Culinary *Gnetum* consists of two species, *G. africanum* and the related *G. buchholzianum*. It is eaten raw or cooked in soups and salads. The leaves contain C-glycosylflavones, 2″-xylosylisoswertisin and 2″-glucosylisoswertisin, 2″-*O*-rhamnoylisoswertisin, and apigenin-7-hesperidoside. Stilbenes, as well as their dimeric, polymeric, and hydroxylated derivatives have been isolated from some *G. africanum* and other *Gnetum* species. It has antioxidant, antidiabetic, and anti-inflammatory properties. It has some not fully characterized oestrogenic activity, which is suggestive of a possible role in women's health.

Pharmacognostical Profile

Botanical Name: *Gnetum africanum* Welw.
Synonym: *Thoa africana* (Welw.) Doweld
Related Species: *Gnetum buchholzianum* Engl.
Family: Gnetaceae
Common Names: Gnetum, eru
African Names: Efik (Nigeria): áfàng; Ibibio: afang; Igbo: okazi, ukazị; Yala (Ogoja, Nigeria): eruru; Yoruba: àjáàbalè, ajakobale

Description: *Gnetum* is a dioecious liana up to 10 m long, but sometimes longer, that grows in the wild in West and Central Africa; the branches are somewhat thickened at the nodes and glabrous. The leaves decussately opposite, sometimes in whorls of three, simple; the stipules are absent; the petiole up to 1 cm long, canaliculate above; the blade ovate-oblong to elliptical-oblong, rarely lanceolate, 5–14 cm × 2–5 cm, base attenuate, apex abruptly acuminate, obtuse or minutely apiculate, entire, thick-papery, glabrous, pale green above, paler beneath, with 3–6 pairs of strongly curved lateral veins looped near the margin. The inflorescence is an unbranched catkin, axillary or terminal on a short branch, solitary but male inflorescences at the apex of branches often in groups of three, up to 8 cm long, jointed, peduncle 1–1.5 cm long, with a pair of scale-like, triangular bracts; the male inflorescence with slender internodes and whorls of flowers at nodes; the female inflorescence with slightly turbinate internodes and 2–3 flowers at each node. The flowers are small, c. 2 mm long, with moniliform hairs at base and an envelope; the male flowers with a tubular envelope and exerted staminal column bearing two anthers; the female flowers with copular envelope and naked, sessile ovule. The seed resembles a drupe, orange-red when ripe ellipsoid, 10–15 mm × 4–8 mm, enclosed in the fleshy envelope.[1]

Culinary (Food) Use: Both species are used a vegetable, eaten raw, or cooked in soups and salads.

Ethnomedicinal Uses: The aerial parts have been used in traditional medicine for the treatment of diabetes, piles, and high blood pressure and also as a medicine against enlarged spleen and sore throat and as a purgative. In the Central African Republic, the leaves are eaten to treat nausea and as an antidote to arrow poison made from *Periploca nigrescens* Afzel. In Cameroon, the leaves are chewed to mitigate the effects of drunkenness and they are taken as an enema against constipation and to ease childbirth. They are also used to treat boils and fungal infections on the fingers.[4]

Constituents: *Gnetum* leaves contain C-glycosylflavones, 2″-xylosylisoswertisin, and 2″-glucosylisoswertisin. Perhaps of chemotaxanomic importance is the presence of 2″-*O*-rhamnoylisoswertisin and apigenin-7-hesperidoside and the absence of vitexin and 2″-*O*-glycosylvitexin in *Gnetum africanum*.[326] Stilbenes, as well as their dimeric, polymeric, and hydroxylated derivatives have been isolated from some *G. africanum* and other *Gnetum* species.

Pharmacological Studies: Most of the studies on eru are on its nutritional properties. It has been shown that extracts of leaf of *Gnetum africanum* induced vaginal openings and increase weights of the uterine muscle in a manner similar to the effect of repeated administration of estrogen to immature female rats. The uterine muscle enlargement suggests the antifertility potential of the popular vegetable in the female reproductive system of rats.[327] However, the result on rats may not correlate directly to human use. The antioxidant quality of *Gnetum* has been evaluated by the determination of lag-time, concentration of polyphenol that will inhibit 50% of oxidation of LDL + VLDL (IC_{50}) and phenol antioxidant index (PAOXI). It was observed that both hydrolyzed and nonhydrolyzed extracts were better antioxidants than vitamin E in the inhibition of copper mediated LDL + VLDL oxidation.[328] This observation is interesting in view of the reported presence of the antioxidant compound resveratrol and stilbenes in *Gnetum*.[329,330]

Agriculture: *Gnetum* is still collected from wild species. But trial cultivations have begun in Cameroon, Nigeria, and the Benin Republic. The main problem is that the plant in its natural habitat seems to prefer shaded forest canopies. In experiments in Cameroon, propagation by seed was difficult because the seed is slow to sprout, germination taking 1 year or more. Perhaps the seeds need pretreatment, such as passing through the intestines of a bird, fruit bat, squirrel, or other animal, before they germinate. Seed is normally found only in the tree canopy. Seed collection is thus far from easy, a further reason why eru is hardly cultivated.[1] Experimental cultivation using leafy stem cuttings have produced encouraging results.

Commerce: Even with the little work done on the chemistry and pharmacology of eru, there is already a high demand for this highly priced and much prized vegetable. With its remarkable antioxidant profile and reputed nutrient properties, the current trade within the West and Central African zone will likely expand. The major limitation remains the scarcity of the plant in the wild.

Gongronema: Utazi

Overview

Utazi is a bitter-tasting vegetable that is consumed in Africa as a potherb. It has an initial sharp-bitter and sweet taste and is widely used as a leafy vegetable and as a spice for sauces, soups, and salads. The leaves contain amino acids, proteins, polyphenols essential oils, and saponins. The fixed oil contains saturated (50.2%) and unsaturated (39.4%) fatty acids, which is a very healthy mix of fatty acids. The most common functional food use of Utazi is as an antidiabetic and as a prebiotic agent. The leaf extracts also showed antioxidant, anti-inflammatory, hepatoprotective, antiplasmodial, antiasthmatic, antisickling, antiulcer, analgesic, antipyretic, gastrointestinal relaxing, laxative, and stomachic activities.

Pharmacognostical Profile

Botanical Name: *Marsdenia latifolia* (Benth.) K.Schum.

Synonyms: *Gongronema latifolium* Benth; *Marsdenia glabriflora* Benth.; *Marsdenia leonensis* Benth.; *Marsdenia racemosa* K.Schum.

Related Species: *Gongronema angolense* (N.E.Br.) Bullock

Family: Apocynaceae (Asclepiadaceae)

Common Names: Bush buck, tafel boom

African Names: Igbo (Nigeria): utazi; Yoruba (Nigeria): arokeke; Ghana: aborode, akam, nsurogya



Description: *Gongronema* is a small genus comprising five species in Africa, much resembling *Dregea*. APG has assigned the subject species *G. latifolium* as member of the genus *Marsdenia.* The name *Gongronema*, however, is used here for ease of cross-reference with earlier information on this medicinally important plant. It is a weak climbing plant with a soft and fibrous stem. The stem is green with little swollen internodes. Both the stem and leafy stalk produce milky latex when cut. The leaves are cordate at the base and a little pointed at the apex. The leaves are smooth. The flowers are cream, and the fruits are ovoid in shape. When dried, they split to expose woolly materials.

Habitat and Distribution: Gongronema is widespread in tropical Africa and occurs from Senegal east to Chad and south to DR Congo.

Culinary (Food) Use: It is widely used as a leafy vegetable and as a spice for sauces, soups, and salads.

Ethnomedicinal Uses: *Gongronema latifolium* is widely used in West Africa for medicinal and nutritional purposes. Leaves of *Gongronema* are used as a bitter tonic to treat loss of appetite and for the management of diabetes. It is also used for hypertension and cholesterol control. An infusion of the aerial parts is taken to treat cough, intestinal worms, dysentery, dyspepsia, and malaria. It is taken with lime as a purge to treat colic and stomachache in Sierra Leone. The pulverized leaves are applied as an embrocation in Senegal and Ghana on the joints of small children to help them walk. The boiled fruits in soup are eaten as a laxative. In Nigeria, a leafy stem infusion is taken as a cleansing purge by Muslims during Ramadan. The latex is applied to teeth affected by caries. It is also taken

for controlling weight gain in lactating women and overall health management. Asthma patients chew fresh leaves to relieve wheezing. A cold maceration of the roots is also taken as a remedy for asthma. A decoction of the roots, combined with other plant species, is taken to treat sickle cell anemia. A maceration of the leaves in alcohol is taken to treat bilharzia, viral hepatitis, and as a general antimicrobial agent.[1]

Constituents: The leaves contain preganane glycosides, 17β-marsdenin derivatives, β-sitosterol, lupenyl cinnamate, lupenyl acetate, lupeol, essential oils, and saponins. The main components of the essential oil from the leaves are linalool (19.5%), (*E*)-phytol (15.3%), and aromadendrene hydrate (9.8%). The fixed oil contains saturated (50.2%) and unsaturated (39.4%) fatty acids. Palmitic acid accounted for 36% of the total fatty acid content; minor saturated fatty acids are stearic acid (4.6%), behenic acid (3.7%), and arachidic acid (2.8%). The main unsaturated fatty acid is linoleic acid (31.1%), followed by oleic acid (7.1%) and linolenic acid (7.1%). The nutritional composition of the dry leaves is crude protein (9.8%–27.2%), lipid extract (6.1%), ash (5.8%–11.6%), crude fiber (8.7%–10.8%), tannin (0.3%), and nitrogen-free extractives (44.3%). The composition of minerals per 100 g dry matter is K 244.8–332.1 mg, Na 110–113 mg, Ca 115.4–154 mg, P 125.5–326.9 mg, Fe 7.8 mg, Zn 13.4 mg, Pb 0.2 mg, Cu 2.3–43.5 mg, Mg 53.8 mg, Cd 0.1 mg, Co 115.9 mg, oxalate 70 mg, and ascorbic acid 187.1 mg. The major essential amino acids are leucine, valine, phenylalanine, aspartic acid, glutamic acid, and glycine.[1]

Pharmacological Studies: Several laboratory studies have demonstrated the possible antidiabetic activity of *Gongronema*. Different alcoholic leaf extracts showed promising hypoglycemic and antihyperglycemic activities in a dose-dependent way on normal and alloxan-induced or streptozotocin-induced diabetic rabbits.[1,331–333] An ethanolic leaf extract possessed significant antilipid peroxidative activities. In a small clinical trial, the blood glucose concentration of healthy humans was determined after consumption of the leaves, and showed a significant reduction in blood glucose level. Leaf extracts also showed antioxidant, anti-inflammatory, hepatoprotective, antiplasmodial, antiasthmatic, antisickling, antiulcer, analgesic, antipyretic, gastrointestinal relaxing, laxative, and stomachic activities. The antimicrobial activity of essential oil and extracts of *Gongronema* has been demonstrated on bacterial isolates from the bloodstream of HIV-infected patients.[334] The leaf extract has also been shown to be protective against acetaminophen hepatic toxicity in Wistar rats.[335]

Toxicity: *Gongronema* is considered a nontoxic vegetable. An oral toxicity test on rats gave an LD_{50} of 1450.5 mg/kg, and an intraperitoneal injection in mice gave an LD_{50} of 1678.6 mg/kg.

Agriculture: The herb is cultivated in gardens and homestead farms in Nigeria and other parts of West Africa. It can be propagated by seed or softwood, semihardwood, and hardwood cuttings. Fresh seeds have a germination rate of up to 85% at 25–29°C. Cold storage for a brief period improves seed germination. Seeds from green-yellow follicles are matured enough to germinate, and can be stored for a longer period than seeds from yellow follicles. Softwood stem cuttings have a better shoot and root development during the wet season, whereas semihardwood and hardwood cuttings perform better during the dry season.[1]

Commerce: A relatively modest trade in *Gongronema* occurs throughout West Africa but mainly for its use as a bitter vegetable and spice. Its importance lies as a dietary supplement base on pharmacological activities, including hypoglycemic, antioxidant, anti-inflammatory, hepatoprotective, antiplasmodial, antiasthmatic, antisickling, antiulcer, analgesic, and antipyretic activities.

Formulation and Dosage Forms: *Gongronema* is an ingredient in two commercial products: Physogen Tea (for diabetes by Neimeth Pharmaceuticals) and a general bitter tonic by InterCEDD Health Products. *Gongronema* has also been used experimentally with positive results to replace hops as a bitter principle in brewing beer.

Gorli

Overview

Gorli (*Caloncoba echinata)* is known for its characteristic small whitish flowers, borne in the axils of the leaves, and in clusters on common stalks, which are a few millimeters long. It is consumed as an occasional or seasonal fruit. Not much pharmacological work has been done on the plant but a high scientific interest is on its constituents which include friedelane triterpenes, kokoonol, kokoonal found in the stem bark, and cycloartane-type triterpenoids, glaucartanoic acids A and B isolated from the fruits. Extracts of the plant are potential anti-inflammatory and chemoprotective agents.

Pharmacognostical Profile

Botanical Name: *Caloncoba echinata* (Oliv.) Gilg.
Synonym: *Oncoba echinata* Oliv.
Family: Achariaceae
Common Name: Gorli
African Names: Igbo: udara-nwewe; Bini: otiemme; Yoruba: kakandika



Description: A shrub or small tree about 7 m high, 1 m or less in girth, with a hard, grayish bark that appears somewhat corrugated. The leaves are yellowish-green in color, oblong elliptic, about 10–30 cm long and 5–10 cm broad. It is narrowly acuminate, entire, with apex long and tapering, and the base rounded. They have a thin and slightly leathery texture. The lateral veins (5–6 pairs) are prominent and run wide angles to the midrib, looping well away from the margins. The stalks are about 2.5 mm long. The plant produces small whitish flowers, borne in the axils of the leaves, and in clusters on common stalks, which are a few millimeters long. The sepals are about 2.5 mm long, and the petals 3–4 mm. It flowers from May to November and the fruiting begins in August and lasts to May. The fruits are round, yellow or orange-red in color, bear numerous prickles (echinate), about 4 cm in diameter, and contain many black or brown seeds, which are embedded in a white, pithy pulp.

Habitat and Distribution: Forest tree, mainly in undergrowth and secondary clearings; occurs in west, central, and parts of southeast regions of the continent.

Culinary (Food) Use: The fruit pulp is used by the Mendes of Sierra Leone to prepare a sweet refreshing drink. The seeds when chewed are sweet and oily and leave a peculiar aromatic aftertaste.

Ethnomedicinal Uses: The seed oil has been used for making soaps and candles. The plant has a reputation as a drug for the treatment of leprosy and was cultivated in the past for this purpose. The seeds of *Hydnocarpus wightiana* are, however, preferred for the treatment of leprosy. A lotion made from the plant has been used in parts of West Africa for pustular eruptions of the skin.

Constituents: The seeds contain oil whose fatty acids have the cyclopentane nucleus of chaulmoogric acid. The acid is used in a mixture with hydnocarpic acid for treating leprosy. The stem bark contains friedelane triterpenes, kokoonol, 3β,21β-dihydroxy-30-nor-(D:A)-friedo-olean-27-oic acid,[336] as well as cycloartane-type triterpenoids, glaucartanoic acids A and B, which were also isolated from the fruits.

Pharmacological Studies: *Caloncoba echinata* has not been investigated much pharmacologically. The cycloartanes isolated from the fruits of the related *C. glauca* have been found to possess cytotoxic activity.[337]

Griffonia

Overview

Griffonia is a woody climbing shrub native to West and Central Africa. It is used as chewing sticks for tooth cleaning and added to palm wine to give it a bitter punch. The seeds contain very high levels of 5-hydroxy-L-tryptophan (5-HTP), up to 18%. The leaves contain volatile oil and amino acid derivatives. The plant is valued as a source of natural 5-HTP, which increases the synthesis of serotonin in the central nervous system and has been shown to be effective in treating a wide variety of conditions, including depression, fibromyalgia, obesity, chronic headaches, and insomnia. It is a major article of commerce.

Pharmacognostical Profile

Botanical Name: *Griffonia simplicifolia* (DC.) Baill

Synonyms: *Bandeiraea simplicifolia* (DC.) Benth.; *Schotia simplicifolia* M. Vahl ex DC.

Family: Leguminosae

Common Names: Griffonia

African Names: West Africa: atooto, gbobgotri, kajya, kanya, kwakuo-aboto

Description: *Griffonia simplicifolia* grows to about 3 m, and bears greenish flowers followed by black pods. The leaves are alternate, simple, and glabrous; the stipules are triangular, 1 mm long, soon falling; the petiole up to 1.5 cm long; the blade ovate, 6–12 cm × 3–6 cm, the base rounded to cordate, the apex rounded to short-acuminate, 3(–5)-veined from the base, reticulate veins prominent on both sides. The inflorescence is an axillary, pyramidal raceme 5–20 cm long; bracts and bracteoles triangular, very small, persistent. The flowers are bisexual, almost regular, 5-merous; the pedicel is 3–4 mm long; the receptacle urn-shaped, 1–1.5 cm long, pale green; the calyx tube 12–15 mm long, orange, lobes triangular,

up to 2 mm long; the petals are almost equal, elliptical, 10–12 mm long, fleshy, greenish, sparsely short-hairy on the margin; the stamens 10, filaments filiform, up to 2 cm long; the ovary superior, c. 4 mm long, stiped, style 1–2 mm long, persistent, stigma small. The fruit is an oblique-cylindrical pod c. 8 cm × 4 cm, stipe 1–1.5 cm long, inflated, leathery, 1–4-seeded.[1]



Habitat and Distribution: *Griffonia simplicifolia* is native to West Africa and parts of Central Africa. It grows in grass savanna, in coastal plains on termite mounds, in scrub thickets, secondary and disturbed forest, and along the margins of primary forest and old farms.

Ethnomedicinal Use: The peeled stems and roots are used as chewing sticks and in Ghana are also beaten into fibers to yield chewing sponges, a popular means of tooth cleaning. The leaf extract is used for kidney diseases and migraine and as an aphrodisiac. It is also used as eye drops to cure inflamed eyes. The aerial parts have been used for wound dressing, as an enema for erectile dysfunction, vomiting, and mental disorders. The pulp is used in Côte d'Ivoire, Ghana, and Nigeria for the treatment of syphilitic sores. A decoction of stems and leaves is taken as a purgative to treat constipation and is used externally as an antiseptic wash to treat suppurating wounds. Stems and stem bark are made into a paste that is applied to decaying teeth, and a paste made from the leaves is applied to burns. In Nigeria, an extract from the powdered roots has been used to treat sickle cell anemia. The leaves are used in the production of palm wine, and give the wine a bitter taste. Sap that exudes from cut stems can be drunk to quench thirst. In Ghana, the roots are chewed and dried to produce a white powder that is used by women to powder their face. The leaves are highly valued as animal feed and are said to stimulate reproduction.

Constituents: The leaves of *Griffonia simplicifolia* contain volatile oil, 5-hydroxy-L-tryptophan (5-HTP), indole-3-acetyl-aspartic acid, 5-hydroxy idole-3-acetic acid (5-HIAA), 5-hydroxytryptamine (=serotonin, 0.1%–0.2%), and coumarone. The seeds contain very high levels of 5-HTP, up to 18%. The cyanoglucoside lithospermoside (=griffonin) has been isolated from the roots and it is believed to be the active ingredient against sickle cell anemia.

Pharmacology: *Griffonia* is valued for the high content of 5-HTP in the leaves and seeds. In humans, 5-HTP increases the synthesis of serotonin in the central nervous system and has been shown to be effective in treating a wide variety of conditions,

including depression, fibromyalgia, obesity, chronic headaches, and insomnia. 5-HTP is poisonous to insects, that is, bruchids (*Callosobruchus maculatus*).[1] The potential of *Griffonia* in the treatment of anxiety states has been evaluated in laboratory animals. *Griffonia simplicifolia* seed extract was shown to exert anxiolytic-like effect in rats. *Griffonia simplicifolia* seed extract, dosed at 1, 5, 10, and 25 mg/kg, was orally administered in rats that were submitted to the dark–light test and open field test, 60 min after the treatment. In the dark–light test, the administration of the extract at the doses of 10 and 25 mg/kg was able to significantly increase the time spent in the light compartment ($P < 0.05$). In the open field test, the extract dosed at 5, 10, and 25 mg/kg induced an antitigmotactic effect, as indicated by a significant increase of time spent in the central area of the open field ($P < 0.01$).[338]

In the sexual behavior of Sprague–Dawley male rats, acute treatment significantly increased mount latency (at any dosage), intromission and ejaculation latencies (at 100 mg/kg), and postejaculatory interval (at 50 and 100 mg/kg). It was also found that subchronic treatment failed to exert a significant influence on copulatory behavior. The daily administration of the extract dosed at 50 and 100 mg/kg for 9 days significantly reduced food intake and body weight. In female rats, however, a single administration of *G. simplicifolia* significantly reduced lordosis response and increased rejection behavior in female rats treated with the highest dose while it did not influence proceptive behaviors. On the other hand, the subchronic administration of the extract significantly reduced proceptivity but not receptivity, and increased rejection behavior. It was found that all tested dosages were able to markedly decrease food intake and body weight after a 9-day treatment. Taken together, the present results, possibly ascribed to increased levels of 5-hydroxytryptamine (5-HT) in the brain, suggest a cautious administration of the plant extract owing to its negative influence on female sexual behavior.

Several clinical studies have established the value of *Griffonia* and 5-HTP in the management of depression.[3] It has been observed that *G. simplicifolia* extracts direct modulation of the serotonergic system and have clinically demonstrable value for the treatment of psychological suffering associated with unreciprocated romantic love.[339]

Commerce: The seed of *Griffonia simplicifolia* is exported to Europe from Ghana, Côte d'Ivoire, Nigeria, and Cameroon. Exports from Ghana account for more than 60% of the global market for the unprocessed seeds as an industrial source of 5-hydroxytryptophan (5-HTP). The annual export to Western Europe was about 120 tons in 2010 at a wholesale price of US$ 15 per kg.

Agriculture: *Griffonia* is still collected mostly from the wild. Domestication efforts have met limited success. In productivity trials, wildlings were successfully used as planting material; this is impractical at a larger scale. The use of stem cuttings has not been successful. Seed propagation gave poor results and different seed treatments did not improve germination.

Guava

Overview

Guava is a delicious edible fruit consumed worldwide and the juice is used as a refreshing drink. The fruits are rich in vitamins (A and C), iron, calcium, and phosphorus. The major

constituents of the essential oil from the leaves are caryophyllene, nerolidiol, β-bisabolene, and β-sitosterol, and ursolic, oleanolic, crategolic, and guayavolic acids. The plant also contains leukocyanidins, sterols, and gallic acid in the roots. The leaves have been investigated for numerous activities and the essential oil has been incorporated in formulations as a carminative and antioxidant. It showed hepatoprotection, antiallergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, cardioactive, anticough, antidiabetic, anti-inflammatory, and antinociceptive activities, which provided scientific rationale for its traditional uses. Guava leaves have been formulated as teas and health drinks (IHP) for metabolic syndrome complications.

Pharmacognostical Profile

Botanical Name: *Psidium guajava* L.
Synonym: *Guaiava pyrigormis* Gaertn.; *Syzygium ellipticum* K.Schum. & Lauterb.
Family: Myrtaceae
Common Names: Guava
African Names: Hausa: gwabaa; Efik: woba; Igbo: ugwoba; Yoruba: guafa



Description: The plant is a large shrub or small tree up to 10 m high. The stem is slender, usually not exceeding 30 cm in width, the bark is brownish, thin, smooth, and often flaking off in small patches. The leaves are oblong, slightly oval-shaped, and oppositely arranged on the stem and branches, 5–10 cm long, rarely exceeding 15 cm in length. They are light green on the upper surface, and downy and pale green on the lower side. They display prominent nerves in the leave underside. The flowers are white, solitary or a few in a cluster in the axils of the leaves. They are about 2.5 cm in diameter, with numerous stamens that are arranged in groups. The fruits are globose or pyriform, yellow, usually 2.5–10 cm long and 2.5–5 cm in diameter, although horticulture varieties with larger fruits are common. They contain many seeds, and the calyx persist in fruit.[1]

Habitat and Distribution: The plant is a native of Central America but is also found all over Africa in semicultivation.

Culinary (Food) Use: The fruits are edible and the juice is used as a refreshing drink.

Ethnomedicinal Uses: The major ethnotherapeutic use of the plant is in treating malaria; for this purpose, its leaves are used as an ingredient in the preparation of fever "teas." The leaves are also used as part of the potherb used in stem treatment of malaria. A weak

infusion of the leaves and tender branches is dispensed for diarrhea and as a tonic in psychiatry.

Constituents: The fruits are rich in vitamins (A and C), iron, calcium, and phosphorus. The essential oil from the leaves has been shown to contain caryophyllene, nerolidiol, β-bisabolene, and β-sitosterol, ursolic, oleanolic, crategolic, and guayavolic acids. The plant also contains leukocyanidins, sterols, and gallic acid in the roots.

Pharmacological Studies: The aqueous alcohol extract has been shown to exhibit sedative activity. Oral doses of 188.5, 337, and 1131 mg/kg caused a significant dose-dependent decrease of the motor activity for 90 min after the administration of the extract.[340] In rats, the plant significantly decreased, in a dose-dependent manner, the intestinal transit time. It also showed *in vitro* antimicrobial activity against *Escherichia coli*, *Salmonella typhi*, *Staphylococcus aureus*, *Proteus mirabilis*, and *Shigella dysenteriae*.[341,342]

P. guajava has been evaluated in many laboratory studies to validate its antispasmodic and antimicrobial properties in the treatment of diarrhea and dysentery. It has also been used extensively as a hypoglycemic agent. Literature is available on the ability of guava to exhibit antioxidant, hepatoprotection, antiallergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, cardioactive, anticough, antidiabetic, anti-inflammatory, and antinociceptive activities, which provided scientific rationale for its traditional uses.

Apart from its antihyperglycemic properties guava may be beneficial for preventing the cardiovascular complications associated with diabetes. It has been established that nonenzymatic glycosylation (glycation) between reducing sugar and protein results in the formation of advanced glycation end products (AGEs), which is believed to play an important role in diabetes-associated cardiovascular complications. Thus, agents that inhibit the formation of AGEs are believed to have therapeutic potential against diabetic complications. The antiglycative potential of ethyl acetate fraction of *Psidium guajava* has been evaluated by administering the extract into streptozotocin-induced diabetic rats. Daily administration of the extract for a period of 1 month significantly decreased the blood glucose, glycated hemoglobin, and fructosamine levels in a dose-dependent manner. Evaluation of toxicity markers like SGOT and SGPT revealed the nontoxic nature of the extract. The presence of the cardiac isoform of liver alpha-2-macroglobulin, which is a major protein associated with earlier stages of cardiac hypertrophy, was also evaluated. SDS-PAGE analysis showed that the level of this protein decreased significantly in extract-treated groups compared to diabetic control.[343]

A wide range of clinical applications has been suggested for the treatment of oxidative stress, infantile rotaviral enteritis, diarrhea, and diabetes.[344] The dried leaves and extracts of the fruits have been formulated as dietary supplements.

Guinea Pepper

Overview

Guinea pepper or Ashanti pepper grows in the forest regions of the continent. Guinea pepper is also called black pepper. It is used in flavoring soups, sauces, and stews and for preparing special meals for postpartum care after child birth. The plant contains many lignans, including dihydrocubebin, aschantine, and yangambine. The roots yield piperine derivatives, trichostachine, and lignans. The essential oil obtained from the berries has been shown to consist mainly of phellandrene, pinene, and limonene. The berries have been used as ingredients in the reparation of traditional remedies in very small quantities

but it is not clear whether it is for therapeutic effect or as a flavoring agent. Laboratory studies have shown that the Guinea pepper amides possess antimicrobial, anticonvulsant, antihypertensive, sedative, tranquilizing, and insecticidal properties. The seeds have also been shown to exhibit activity against sickle cell disorder. Its effect on the regulation of the female menstrual cycle is worthy of closer study.

Pharmacognostical Profile

Botanical Name: *Piper guineense* Schum. Et Thonn.

Common Name: Bush-pepper, West African black pepper, Ashanti pepper, Guinea pepper

Family: Piperaceae

African Names: Anang: okurusa; Arab (Shuwa): shitta masoro; Ashanti: soro-wisa; Bambara: niamaku; Bakwari (Bota): indoko; Bakundu (Balondo, Batanga): ndonga; Diola: funkungen; Efik: eti-nkeni; Ewe: kale, asonsa; Fanti: sasima; Fulani: chitta masoro; Hausa: masoro; Igbo: uziza; Kanuri: ngolo imassoro; Malinke: fefe; Mano: za wele; Mende: koma-simi, neni; Twi: sesaa, asonsa; Yoruba: iyere, ata iyere

Description: Guinea pepper or Ashanti pepper is a slender climber up to 12 m high, with prominent nodes and clasping roots. The leaves are elliptic in shape, about 15 cm long and 7 cm broad. They are pointed at the apex and rounded and up to 5-nerved at the base. The leaves when crushed have a pleasant aroma. The flowers are small, borne on common stalks as clusters opposite the leaves, or at the terminals of the stem and branches. The fruits occur as racemes, and are red or red-brown and turn black when dry.



Habitat and Distribution: Found in high forest area. Occupy forest clearings and clings on remaining trees in secondary forests. It is widely distributed.

Culinary (Food) Uses: The black berries are used as spice to flavor soup. The oil distilled from them is used for perfumery and soap making.

Ethnomedicinal Uses: The leaves are used to regulate the menstrual cycle and as an ingredient in remedies for female infertility. A weak decoction of the leaves and fresh fruits is used as a cough remedy. The seeds are stomachic and carminative and are indicated especially for griping stomachaches.[1] The plant is a reputed antibacterial agent, and the roots, and fruits are incorporated in preparations for the treatment of infectious

diseases. The roots are listed for gonorrhea, bronchitis, syphilis, and colds; the leaves are applied to wounds; and the seeds are dispensed for bronchial infections. The pulverized seeds are used as an insecticide, and the whole fruit is extracted and employed externally as a stimulating ointment or as a counter-irritant.

Constituents: Several lignans have been reported from the plant, including aschantine and yangambine. The roots yield piperine, trichostachine, and lignans, and the leaves contain the lignin dihydrocubebin.[345] The essential oil obtained from the berries has been shown to consist mainly of phellandrene, pinene, and limonene.[346,347] A phytochemical analysis of the fruits led to the isolation of several amide piperines, including sylvatine, *N*-isobutyloctadeca-*trans*-4-dienamide, Δα,β-dihydropiperlonguminine, Δα,β-dihydropiperine, and trichostachine.[348,349] The plant also contains the pyrrolidine amide wisanidine, piperidine amides, dihydrowisanine,[350] dihydropiperine, wisanine,[351,352] and *N*-formyl piperine.[353]

Pharmacological Studies: The amides have been shown to possess antimicrobial, anticonvulsant, antihypertensive, sedative, tranquilizing, and insecticidal properties.[1] *P. guineense* seeds exhibits activity against sickle cell disorder. The effects have been attributed to the presence of piperine, capsaicin, cubebin, and caryophyllene, or closely related compounds in the plant.[354]

Toxicity: High doses of the herb have been reported to cause convulsions and hematuria.[355]

Gum Arabic

Overview

Gum Arabic or Acacia gum is derived from the hardened sap of two species of the acacia tree: Senegalia (*Acacia senegal*) and Vachellia (*Acacia seyal*). It is cultivated mainly in the Sahel regions of West Africa and Arabia. The gum consists of a complex mixture of glycoproteins and polysaccharides. It is the original source of the sugars arabinose and ribose, both of which were first discovered and isolated from it, and are named after it. Gum arabic is used primarily in the food industry as a food thickener and stabilizer. The soft drink industry is one of the world's largest consumers of gum arabic, which confers a long shelf life to the drinks. The gum is also used as an additive in art products and cosmetics, and a key component of ink-on-paper printing. Gum arabic is the preferred agent for binding different substances together or holding ingredients in a stable suspension for the food and health formulations. This natural gum is used to make a chilled, sweetened, and flavored gelato-like dessert in the Sahel regions of Africa and Arabia.

Pharmacognostical Profile

Botanical Name: *Acacia senegal* (L.) Wild.

Related Species: *Acacia senegal* subsp. *trispinosa* (Stokes) Roberty; *Acacia senegal* var. *samoryana* (A. Chev.) Roberty

Synonyms: *Senegalia senegal* (L.) Britton & P. Wilson.; *Mimosa senegal* L.; *Acacia verek* Guill. Et Perr.; *Acacia circummarginata* Chiov.; *Acacia cufodontii* Chiov.; *Acacia oxyosprion* Chiov.; *Acacia rupestris* Boiss.; *Acacia spinosa* Marloth & Engl.; *Acacia volkii* Suess.; *Acacia senegal* (L.) Britton

Family: Leguminosae

Common Names: Gum Arabic tree (E), Acacia gum, gommier, gommier blane (F).

African Names: Arabic: shagar; Samgh Arabic: konait; Bambara: patukill; Hausa: akovia, dakwara; Fulani: dibehi; Kanuri: kolkol; Ndebele: umhlahalinye; Nyamwezi: katatula, mgwata, kakakantunda; Peuhl: patuki, bulbi; Swahili: kikwata mgunga; Zinza: mkoto

Description: A small tree or shrub, up to 7 m high, with a short bole, gray fissured stem, usually coming off as papery patches to reveal a powdery underlayer. It branches low and its dense foliage gives it the appearance of a somewhat large thorn at the base of the branchlets, with 3–6 pairs of pinnae and 6–15 pairs of narrow leaflets, about 6–8 mm long. The cream-colored, fragrant flowers are borne in axillary clusters, as densely crowded spikes, usually longer than the leaves. The fruits occur as membranous flat cloves, ca. 11 cm long and 2–4 cm wide, hairy and pale brown in color; containing 7 or 8 flat and circular beige seeds.[2,356] It has been proposed that the genus be broken into three: *Acacia*, *Senegalia* (*s.l.*), and *Racosperma*.

Habitat and Distribution: Gum Arabic occurs in the subdesert regions, the Sahelian and dry tropical zones. It is found in Mauritania, Sudan, Niger, Mali, Senegal, Gambia, Nigeria, Burkina Faso, Kenya, Uganda, Tanzania, and parts of southern Africa. There about 163 species of Acacia based on the classification of the *International Code of Botanical Nomenclature*: 52 are native to the Americas, 83 to Africa, Madagascar, and the Mascarene Islands, 32 to Asia, and 9 to Australasia and the Pacific Islands. If the other members of the mega-genus are included, comprising the following genera: *Senegalia*, *Acaciella*, *Mariosousa*, and *Racosperma*, the number rises to 1406 with most of them of Australian origin.[357]

Culinary (Food) Use: In Sudan, Mali, and Northern Nigeria, the natural gum is eaten as snacks and used to make a chilled, sweetened, and flavored gelato-like dessert.

Ethnomedicinal Uses: In West Africa, especially in the Senegal–Gambia region, the gum is used in the preparation of a remedy for dysentery and diarrhea, and applied externally for modular leprosy. In East, Central, and North Africa, the leaves have been used in remedies for ophthalmia, colds, and hemorrhage,[22] and gum for the treatment of local inflammations. The root is used in the mainland of Tanzania as a gonorrhea remedy.

Constituents: The most important constituent of this plant is gum Arabic, a colorless, odorless, nontoxic solid substance, soluble in water (1:2) that forms a sticky solution used in a variety of consumer products.[358] The gum exudes from branches and stripping off a patch of the bark. Gum Arabic consists of a glycosidal acid of high molecular weight that has been termed arabic acid, and it is combined with potassium, magnesium, and calcium. It also contains diastases and oxidase enzyme (African Pharmacopoeia [AP]). Acacia gums consist of galactose, arabinose, rhamnose, and glucuronic acids as the only sugars found in all types of gums. The difference between *A. senegal* and *A. seyal* (and the other Acacia exudates) is the level of each sugar. The polysaccharide fraction is composed of a linear chain of β-1,3-linked galactose. This chain is ramified in position with chains of galactose and arabinose. Rhamnose, glucuronic acid, or methyl glucuronic acid units are found as chain terminations.[359]

Pharmacological Studies: Acacia gum is used in the food industry and pharmacy as a suspending and emulsifying agent, emollient, and adhesive in the manufacture of tablets and other oral dosage forms. Acacia gum is highly appreciated in technical applications due to its unique properties; it is not only used as a film former in the printing industry, or as an adhesive agent in glues, but also as a binding agent when used as a natural substitute for chemicals. The gum's technological properties (texturing and film forming in confectionery, emulsifying, and encapsulating in flavors and colors) and for about 20 years for nutritional properties (fiber and prebiotic) in enriched foods and nutritional complements

makes it the preferred edible industry gum.[360] Various modifications have been made to the natural gum for use in specific pharmaceutical formulations.

The unique properties of Acacia gum have also been adapted to provide protective coating to natural foods. For example, *shiitake* mushroom coated with gum arabic + natamycin (GANA) maintained tissue firmness and showed reduction in microbial counts from yeasts and molds compared with the control. In addition, GANA coating also delayed changes in the soluble solid, total sugar, and ascorbic acid concentration. Sensory evaluation proved the efficacy of GANA coating by maintaining the overall quality of shiitake mushroom during the storage period. The efficiency was better than that of GA or NA treatment alone. Our study suggests that GANA has the potential to improve the quality of shiitake mushroom and extend its shelf-life up to 16 days.[361]

Honeybush Tea

Overview

Honeybush tea is a collective name for several *Cyclopia* species that were originally used as tea in southern Africa but now enjoy worldwide patronage as a caffeine-free, low-tannin beverage. It contains polyphenols, including isoflavones, flavones, flavonols, cinnamic acids, coumestans, xanthonoids, mangiferin, and isomangiferin. Honeybush possesses antioxidant and anti-inflammatory properties.

Pharmacognostical Profile

Botanical Name: *Cyclopia intermedia* E. Mey; *Cyclopia subternata* Vog.; *Cyclopia genistoides* (L.) Vent.; *Cyclopia sessiliflora* Eckl. and Zeyh.; *Cyclopia maculata*; and related species

Family: Leguminosae

Common Names: The various *Cyclopia* species are collectively called "honeybush tea" but the individual species are known by a variety of names, which include

- *Cyclopia intermedia*, known as "mountain tea," found between Port Elizabeth and the edge of the Langkloof
- *Cyclopia subternata*, known as "marshland tea" or "valley tea"
- *Cyclopia genistoides*, known as "coastal tea," found mostly in the Western Cape near Yserfontein and Darling and also thriving in the South Cape if cultivated
- *Cyclopia sessiliflora*, known as "Heidelberg-tee," named after the town Heidelberg in South Africa, where it grows in the local mountain range

African Names: Bergtea (*C. intermedia*), vleitee (*C. subternata*), Kustee (*C. genistoides*)

Description: The genus *Cyclopia* includes over 20 species of shrubs, endemic to the southwest and southeast of South Africa and mainly associated with fynbos plant formation. They are collectively called "honeybush tea" and their leaves are commonly used to make tisanes or "herbal teas." It has many similarities with rooibos. Honeybush is so named because the flowers smell of honey. The taste of honeybush tea is similar to that of rooibos but a little sweeter. Both are devoid of caffeine and much more fragrant than any

true tea prepared from *Camellia* species, or even other tisanes. In some rural districts, it is used to be common practice to keep a kettle of honeybush tea infusing on the stove ready for drinking while scenting the whole house—unlike tea prepared from *Camellia sinensis*, the product does not rapidly spoil as it simmers.



Most *Cyclopia* species have resisted attempts at domestication or cultivation and must be harvested in the wild although a few can be cultivated. The major problem has been poor knowledge of the ecology of fynbos. It is not always easy to discover what the seeds need to enable germination; some kinds bear elaiosomes and might be dependent on the services of particular ants or birds. *C. intermedia* is one of the teas harvested in the Kouga mountains where it grows naturally. Mountain tea regenerates within 3 years after harvesting or devastation by fire; consequently, less than one-third of the mountain yield is available for harvesting each year by rotation. Mountain tea and valley tea flower in September/October whereas coastal tea flowers in May/June.

Culinary (Food) Use: It is used as a caffeine-free tea.

Constituents: Honeybush does not contain caffeine and is low in tannin (0.45%) but rich in minerals. Some of the active compounds found in honeybush include isoflavones, flavones, flavonols, cinnamic acids, coumestans, xanthonoids, mangiferin, and isomangiferin.

Pharmacological Studies: The antioxidant activity and antimutagenic activity of the aqueous extracts of both fermented and unfermented honeybush tea have been established by several studies.[362] In a comparative study on the antioxidant activities of *Cyclopia intermedia*, *Aspalathus linearis* (Rooibos), and *Hibiscus sabdarifa* (Zobo), it was found that the anti-free radical potential (removal of hydroxyl radicals and superoxide anions) of honeybush extract was lower than in water infusions of rooibos, which is probably due to the lower concentration of polyphenols in the honeybush tea, but higher than the antioxidant activity of *H. sabdariffa*.[363] It has been shown that the degree of antimutagenic activity of honeybush varies according to the type of mutagen tested. For example, extracts demonstrated stronger protective activity against mutagens, which require metabolic activation, such as 2-AAF and AFB1. Significant differences were also observed in antimutagenic activity between various honeybush species and between extracts from nonfermented and oxidized material. Research showed that nonfermented material has a higher antioxidant and antimutagenic potential, both *in vitro* and *in vivo*. Depending on the type of mutagen, research model, honeybush species, and the type of material used, extracts from *Cyclopia* plants demonstrated antimutagenic activity that are comparable with extracts from green, black, and rooibos teas.

The phytoestrogenic activity of extracts of honeybush has only been demonstrated *in vitro*. Their antimicrobial activity has also not been well established.[364] The chemical

constituents found in honeybush tea have been linked to the activities of the extracts. Although not backed by conclusive experiments, the following inferences have been drawn by promoters of honeybush as a dietary supplement:

Isoflavones and Coumestans:

- Regulation of menstruation cycles
- Prevention of breast, prostate, and uterus cancer
- Reduces the risk of oesteoporosis
- Antifungal properties
- Antivirus properties
- Anticholesterolemic—lowers cholesterol levels
- Hypolipidemic—lowers fat levels
- Antimicrobial
- Antioxidant

Xanthones:

- Anti-inflammatory
- Antihepatotoxic
- Antivirus
- Antidiarrhea
- Antifungus
- Antioxidants
- Antidepressant

Flavones:

- Vitamin-type activity (mixture of eriodictyol and hesperidin)
- Antioxidants
- Antimicrobial
- Antivirus
- Anti-inflammatory
- Spasmolytic
- Diuretic (increases urination)
- Nonfeeding sweeteners

Commerce: *Cyclopia* species have now become established commercial teas but not as popular as rooibos tea. The biggest hindrance to its commercial growth is the fact that honeybush is not one distinct species and trade in the tea varies according to region. Differentiation of the four major commercial species is often difficult. Microscopic pharmacognostical profiling, using the leaf and stem microstructure of the species, has proved useful in the determination of ultraspecific identity of the commercially important *Cyclopia* species (*Cyclopia intermedia*, *Cyclopia subternata*, *Cyclopia maculata*, and *Cyclopia genistoides*). Leaflet characters of diagnostic value include the shape, margin (flat or revolute), bundle sheath extensions, crystals (aggregates, solitary crystals, and crystal sand), relative size of

the upper and lower epidermal cells, and thickness of the cuticle. The study also revealed an abundance of phenolic compounds, not only in the leaf epidermal cells and leaf bundle sheaths, but also in the secondary phloem, xylem rays, xylem parenchyma, and pith, showing that the inclusion of older stems may be acceptable and does not necessarily lower the quality of the product.[365]

Agriculture: Like most members of the fynbos ecosystem, honeybush tea plants are not easy to cultivate. Some of the species are nonsprouting, which means that replanting requires a lot of care but once the plant is established, it is a hardy shrub. The lifespan of the nonsprouters is 7–8 years while that of sprouters is estimated to be at least 10 years, based on the productive age of the oldest *C. genistoides* plantation.[366]

Indian Ginseng

Overview

Withania somnifera, a member of the nightshade family, is widely distributed from the Canary Islands and the Mediterranean region through Africa, the Middle East, India, and Sri Lanka to China. It also occurs in Australia. In Africa, it occurs wild or naturalized throughout the drier parts of the continent, including South Africa and in several Indian Ocean islands. The plant contains distinctive group of phytosteriods called withanolides, including their glycosides and chlorinated derivatives. A group of *Withania* alkaloids has been isolated exclusively in the plant, including ashwagandhine, ashwaganidhine, and somniferine. The plant also contains volatile oil, tannin, and fatty acids. It has been reported that it contains the unstable alkaloid, cuscohygrine, which is an oil that can be distilled without decomposition only in vacuum. It is soluble in water and forms a crystalline trihydrate, which melts at 40–41°C. *Withania somnifera* is considered an adaptogenic agent and has therefore been suggested for a battery of laboratory studies, both *in vitro* and *in vivo* to establish its antioxidant, anti-inflammatory, immune-boosting, and brain function enhancement activities. In clinical medicine, it is employed in India to attenuate cerebral function deficits in the geriatric population, to augment the faculty of learning and memory retention in normal individuals, and to provide nonspecific host defense. It has been used as a hypnotic in clinical cases of emphysema, alcoholism, and pulmonary tuberculosis; as an antidepressant, anti-inflammatory, antiaging medication to support brain function, and in Parkinson's disease; as a cardiotonic; and as a general tonic. It has also been used for the treatment of male infertility.

Pharmacognostical Profile

Botanical Name: *Withania somnifera* (Linn.) Dunnal

Synonym: *Physalis somnifera* L.; *Withania microphysalis* Suess.

Family: Solanaceae

Common Names: Indian ginseng, ashwagandha

African Names: Masai: ol asajet; Nyamwezi: kuvia; Sotho: bofepha, moferangopa, mosala-marupi; Swati: vinhepi; Xhosa: ubuvuma; Zulu: umuvimba

Description: *Withania somnifera* is an erect, much-branched undershrub, growing up to 2 m high with distinctively hairy stems. The leaves are simple, about 10 cm long, elliptic to

broadly ovate-lanceolate, with entire or wavy margins. The flowers are small, about 1 cm long, greenish or yellow, occurring in short axillary clusters. It produces red globes, fruits, ca. 6 mm in diameter, enclosed in the inflated and membranous calyx.



Habitat and Distribution: It grows in the drier tropical regions. It is distributed from Liberia to Nigeria, South Africa, and the southeast islands.

Culinary (Food) Use: The leaves are sometimes eaten as a vegetable, but there are several reports that they are poisonous. The berries are used to curdle milk to make cheese.

Ethnomedicinal Uses: In West African folk medicine, both roots and leaves are used internally, and the freshly pounded leaves (also used internally) are used against fever, chills, and rheumatism, among several other uses. In southern Africa, the Sotho uses the plant as an anthelmintic and as a ritual plant against witchcraft. The Zulu administer an enema of the decorticated root for the treatment of hyperpyrexia in infants. The Xhosa and the Pedi use the plant to disinfect meat, particularly that suspected to be infected with anthrax. A decoction of the root and leaf is used by the Swati for the treatment of eruptive diseases such as smallpox. The plant is reported to be used in southern Africa in the treatment of asthma and bronchial diseases, syphilis and other venereal infections, as a remedy for "blach gall sickness," and as a general antiseptic for wound dressing.

Constituents: The plant contains alkaloids (e.g., withanine) and a distinctive group of phytosteriods called withanolides. Withaferin A isolated in 1965 by Lavie et al. is the prototype of this group of chemotaxonomically important phytosteroids. Since then a number of related withanolides have been isolated including some naturally occurring chlorinated derivatives. The glycosylated derivatives have also been isolated, for example, sitoinoside IX (withaferin A-C27-*O*-β-D-glucoside) and sitoinoside X (*6'-O*-palmitoylwithferin-A-C27-*O*-β-D-glucoside), which occur in the root of several varieties of *W. somnifera*.[367] The plant also contains volatile oil, tannin, and fatty acids.

Pharmacological Studies: In India, the plant is well known in folk medicine as a sedative, general tonic, and antihypertensive agent.[368] The withanolides have different effects on the immune systems. Withaferin A, for example, produced suppression of adjuvant-induced arthritis in rats and locally induced graft (lymphocytes) versus host reactions in chicks,[369] as well as causing depletion of murine splenic cells *in vitro* in the presence or

absence of mitogenic stimulant.[370] Similar immunostimulant activities have been reported for other structurally related withanolides.[371,372]

An aqueous extract of the roots of *W. somnifera* has, however, been reported to have an immunostimulatory effect[1]; this report appears contradictory to the published immune depressant effect cited above. The likely explanation is that the drug, which is employed as an adaptogenic agent, possesses components with both stimulatory and depressant action on the immune system. The aqueous suspension of the root has been shown to abolish the neutropenia induced by a single dose of cyclophosphamide (200 mg/kg s.c.) and in neutropenic mice infected with *Staphylococcus aureus*, pretreatment with *W. somnifera* reduced the mortality due to sepsis from 75% in the control group to 50%. The treated animals developed significant leukocytosis and neutrophilia and demonstrated significant inhibition of leukopenia and neutropenia due to cyclophosphamide-induced myelosuppression. The extract was found to be effective as an immunostimulant in surgically induced immunosuppression in mice.

Ghosal et al. reported the isolation of two withanolide glycosides, sitoinosides IX and X, as the constituents responsible for the immunostimulant activity of the plant.[373] At a dose of 100–400 μg/mouse, the two compounds produced statistically significant mobilization and activation of peritoneal macrophages, phagocytosis, and increased activity of lysosomal enzymes secreted by the activated macrophages. The two compounds at a dose of 50–200 mg/kg p.o. also produced significant antistress activity in albino mice and rats, and augmented learning acquisition and memory retention in both young and old rats.[1]

Withania also showed potent analgesic and antipyretic effect with the absence of gastric damage at different dose levels in experimental rats and it compared favorably with the nonsteroidal anti-inflammatory drug (NSAID) indomethacin. Its anti-inflammatory properties have been evaluated by measuring the paw volume and serum lysosomal enzyme activities in monosodium urate crystal-induced rats.[374] It is effective in treating obsessive compulsive disorder in experimental animals and the activity compares favorably with standard anxiolytic drugs such as fluoxetine, ritanserin, and parachlorophenylalanine.[375]

Clinical Properties: *Withania somnifera* is employed in Indian Ayurvedic medicine to attenuate cerebral function deficits in the geriatric population, to augment the faculty of learning and memory retention in normal individuals, and to provide nonspecific host defense.[376,377] It has been employed as a hypnotic in clinical cases of emphysema, alcoholism, and pulmonary tuberculosis.[378] *Withania* is used in clinical medicine as a treatment for depression and inflammation; as an antiaging medication to promote brain function and manage Parkinson's disease; and as a cardiotonic and as a general tonic.

It has been used for the treatment of male infertility in India. In a clinical report of the treatment of infertile men ($n = 75$), *Withania* recovered the seminal plasma levels of antioxidant enzymes and vitamins A, C, and E and corrected fructose metabolism. The treatment with *W. somnifera* effectively reduced oxidative stress, as assessed by decreased levels of various oxidants and the improved level of diverse antioxidants. Moreover, the levels of T, LH, FSH, and PRL, good indicators of semen quality, were also reversed in infertile subjects after treatment with the herbal preparation. *Withania somnifera* inhibited lipid peroxidation and protein carbonyl content and improved sperm count and motility.[379]

Toxicity: No serious side effects or toxicity have been attributed to the consumption of *Withania.* The plant is regarded in India as a general tonic and a casual adaptogen, with ginseng-like activities. In Sri Lanka, an extract of the plant has been reported to have caused marked lesions in feeding experiments with rats.[380]

Kidney Bean

Overview

Kidney bean is the pulse obtained from *Phaseolus vulgaris* that grows in most parts of the continent. The leaves, pods, and seeds are rich in proteins and amino acids. The fresh beans have been found to contain estrone, estriol, and 17α-estradiol. Kidney bean meal is believed to be good for diabetics and in the management of metabolic syndrome. It is a valued staple in many regions of Africa.

Pharmacognostical Profile

Botanical Name: *Phaseolus vulgaris* L.

Synonym: *P. communis* Pritzel.; *P. compessus* DC.

Family: Leguminosae

Common Names: Bean, kidney bean, navy bean, French bean, Haricot (Fr)

African Names: Arabic: fasolia; Hausa: wake; Igbo: akidi, okwe; Swahili: haragwe, haragi; Yoruba: awuje

Description: *Phaseolus vulgaris* is a twinning annual herb, erect or recumbent, with short stems, climbing up a length of 5 m. The leaves are trifoliate, opposite, oval pinnate, and acuminate. It produces whitish flowers with yellow or purple spots. The pods are narrow with a beak at the end and contain seeds of various colors.



Habitat and Distribution: Kidney bean is a cultivated crop grown in most parts of the world. It does not grow well in an atmosphere with high humidity and in lowland areas where it is frequently attacked by pests.

Culinary (Food) Use: Kidney bean is an edible pulse eaten as a cooked staple in many parts of Africa.

Ethnomedicinal Uses: The leaves of the plant are used in the preparations of lotions for external use in the treatment of a variety of skin conditions; a paste made with the crushed bean cake has been applied to cutaneous leishmanial lesions. The bean is eaten as a nutrient during convalescence. Duke[493] listed the plant as carminative, depurative, for acne application, digestive, diuretic, emmenagogue, febrifuge, and cardiotonic, among several other uses.

Constituents: The beans are rich in protein and are recognized as a cheap source of protein. The also contain starch, cyanogenetic glycoside, and a hemaglutin, phaseolitin. The leaves, pods, and beans yield several vitamins and minerals, and enormous variation exists in the ratio of these nutrients in plants from different parts of the world and among different hybrids. The fresh beans have been found to contain estrone, estriol, and 17α-estradiol.[381]

Pharmacological Studies: Phaseolin isolated from the beans has fungicidal activity.[4] Aqueous extracts depress the isolated intestine of the rabbit and guinea pig.[382]

Toxicity: The plant contains up to 0.008% of toxic HCN and the tumor-enhancing phytoglutinin; both constituents are, however, destroyed during cooking. The seeds also contain trypsin and chymotrypsin inhibitors.

Kinkeliba

Overview

Kinkeliba (*Combretum micranthum*) is a caffeine-free beverage used in some parts of West Africa (Guinea, Senegal, Mali, and Burkina Faso) as a tea. *Combretum* species yield catechins, glycosides, choline, organic acids, tannins, and resin. The isomeric flavonoids vitexin and saponaretin have been shown to be present in the leaves. The stem yields alkaloids. Kinkeliba enjoys a lay reputation in West Africa for the treatment of obesity, liver enlargement, and diabetes.

Pharmacognostical Profile



Botanical Name: C*ombretum micranthum* G. Don
Synonyms: *C. altum* Lerr.; *C. floribundum* Engl. & Diels; *C. raimbaultii* Heck.
Family: Combretaceae

Common Name: Kinkeliba bark

African Names: Hausa: geza; Igbo: obi-agwu; Swahili: mlama muepe; yoruba: okan

Description: It is a bushy shrub or creeper, grows up to 20 m in length. The leaves are opposite, oval acuminate with the lamina covered with reddish scales on the inner side with downy tufts at the axis of lateral ribs. The flowers are born as short axillary clusters on scaly stalks, with a whitish corolla and ferruginous scales covering the calyx. The fruits are small, 1.5 m in diameter, scaly and ferruginous, four winged.

Habitat and Distribution: The genus is found all over the continent, but the subject species appears to be dominant in the Savanna belt. It is found from Sudan to Nigeria, and from Gambia to Congo. Several related species are used medicinally in southern African.

Culinary (Food) Use: The leaves are used as a tea substitute in West Africa.

Ethnomedicinal Uses: Decoction of the root of *Combretum micranthum* (also *C. mucronatum*, family Combretaceae) is used in West Africa for the treatment of guinea worm infestation.[383] An oral dose (0.03 g/kg) of the decoction caused a complete extrusion of the worms in 43 of the 44 patients treated. There was a marked reduction in the inflammation around the lesions. Ampofo also found that application of sterilized palm oil aided in the healing of the wounds.[192] *Combretum* has been used as an antidiuretic, anticholagogue, and antibacterial. The leaves of this plant yield a drug called "Kinkeliba," which has been listed in the French, Spanish, and British Extra Pharmacopoeia under supplementary drugs and indicated for blackwater fever and other fevers. A decoction of the leaf and root is applied as a vapor bath, as a wash for febrile conditions, and as a remedy for lumbago. An ointment prepared with the pulverized dry fruits has been used for application to suppurating wounds and abscesses. Various members of the genus are also employed as an anthelmintic in many parts of Africa and Asia. Kinkeliba "tea" is used in West Africa as a general tonic or morning hot beverage as a substitute for tea. It enjoys a reputation in Guinea, Mali, and Senegal as a supplement for the management of diabetes, obesity, and high cholesterol.

Constituents: *Combretum* species yield catechins, glycosides, choline, organic acids, tannins, and resin. The isomeric flavonoids vitexin and saponaretin have been shown to be present in the leaves.[384] The leaves also contain the alkaloids combretacins.[385] The stem bark has been shown to yield similar alkaloids.[386]

Pharmacological Studies: Extracts of the leaves are inhibitory against strains of *Staphylococcus*, *Streptococcus*, and *Escherichia*.[387] The stem bark extract has also been shown to possess broad-spectrum antimicrobial activity.[274] The catechins are strongly diuretic with a mild hypotensive action.[388] The young leaves of a related species *C. racemosum* are effective as an anthelmintic.[389] The aqueous extract of the leaves showed dose-dependent antidiabetic activity on alloxan-induced hyperglycemic rats.[390]

Combretum species have demonstrated significant anti-inflammatory, antiviral, antifungal, and antioxidant activities.[391] The relatively low toxicity of the decoction used as teas makes Kinkeliba a potential dietary supplement for the treatment of the chronic diseases for which it is used in traditional medicine.

Kola Nut

Overview

Kolanut is a caffeine-containing fruit of the trees *Cola nitida* and *Cola acuminata* used as a flavoring ingredient and a central nervous system stimulant. It is a major ingredient

in the original formulation of the popular beverage Coca Cola® and is the origin of the term "cola." It is chewed in West and Central Africa individually or in a group setting as a restorative and an effective appetite suppressant. It is often presented to welcome guests and also used ceremonially in important events like marriages, child-naming ceremonies, and funerals as ritual offering both to living and deceased ancestors. The nut's aroma is sweet and rose-like. Kola nut has an initial bitter taste but becomes sweet upon chewing. The plant contains purines, caffeine, and theobromine, and two phenolic substances, kolatin and kolatein, as well as catechols, (–)-epicatechol, and kolanin. An anthocyanin pigment called Kola red, a phlobaphen, occurs as an oxidation product of the catechols. Kola nut is a powerful antioxidant, anti-inflammatory, and antiobesity agent.

Pharmacognostical Profile

Botanical Name: *Cola acuminata* (P. Beaav.) Schott & Endl.

Synonyms: *Cola pseudo-acuminata* Engl.; *Sterculia acuminata* P. Beauv.; *Cola grandiflora* Schott & Endl.; *Cola ledermannii* Engl. & K.Krause.; *Cola macrocarpa* Schott & Endl.; *Bichea acuminata* (P.Beauv.) Farw.; *Bichea solitaria* Stokes.; *Bichea sulcata* Pierre ex A.Chev.; *Braxipis grandiflora* Raf.; *Braxipis nitida* Raf.; *Clompanus longifolia* Kuntze.; *Colaria acuminata* Raf.; *Edwardia acuminata* (P.Beauv.) Kuntze.; *Edwardia lurida* Raf.; *Sterculia laxiflora* Rusby

Family: Malvaceae

Common Names and African Names are similar in most cases: Bini: evbe; Efik: ibong; Igbo: oji-awusa; Yoruba: obi abata

Description: Resembles *C. nitida* but the leaves are usually smaller. The fruits are composed of up to five carpels borne at right angles to the stalk or slightly drupping; narrowed to the straight apex, 20 cm long and 7 cm wide, producing up to 14 seeds, covered with white skin, usually bearing 3–5 cotyledons (rarely 2 or 6).

Uses, Constituents, and Pharmacology are as in *C. nitida.*

Cola nitida

Botanical Name: *Cola nitida* (Vent.) Schott & Endl.

Synonyms: *Cola vera* K. Schum.; *Cola acuminata* (P. Beauv.) Schott & (Endl.) var. *latifolia* K. Schum.; *Sterculia nitida* Vent.; *Bichea nitida* (Vent.) Farw.

Family: Malvaceae

Common Name: Kola-nut, bitter kola-nut

African Names: Aowin (Sefwi): awase; Arabic: guro, woro; Fanti: bose; Hausa: goro; Igbo: oji; Nupe: chigban'bi; Nzima: esele; Twi (Ashanti, Wasaw): bese, bese-pa; Yoruba: obi gbanja

Description: An evergreen tree, usually 9–12 m high, but sometimes growing up to 20 m and 1.5 m in diameter. It has narrow buttresses, extending for 1 m in old trees, or absent; the bole is not always straight and cylindrical. The bark is gray or grayish-brown, rough with longitudinal fissures, and pinkish-red slash, which darkens to brown on exposure. The leaves are simple, alternate, petiolate; the petiole 1.2–10 cm long; the blade broadly oblong to broadly elliptic or elliptic-oblanceolate, 10–33 cm long, 5–13 cm wide, apex abruptly and shortly acuminate, base obtuse or rounded, margins wavy, glabrous, or nearly so; the leathery, dark-green lateral nerves 6–10, the lowest arising close to the base and running parallel to the margin, obscure above, prominent below. The inflorescence is axillary, on irregularly branched panicles 5–10 cm long, shorter than the leaves; the flowers are unisexual, appearing May–July and fruiting October–December, 5-merous, apetalous.

The male flowers are with cup-shaped calyx, about 2 cm in diameter, deeply lobed, stamens numerous, in two whorls. The female flowers with calyx about 5 cm in diameter, with five carpels and numerous rudimentary anthers at the base. The various kola species can be easily differentiated by their fruits. *C. nitida* are oblong-ellipsoid follicles 13 cm long, 7 cm in diameter, green, shiny surface, smooth to the touch but knobby with large tubercles. It contains 4–6 (sometimes up to 10) seeds per carpel. The seeds are ovoid or subglobose 3–3.5 cm long, 2–2.5 cm in diameter, covered with a white skin and having only two cotyledons, very rarely three.



Habitat and Distribution: The plant is a native to the lowland forests of Sierra Leone, Liberia, Ivory Coast, and Ghana. It has been introduced and is cultivated in Nigeria, Mali, and Guinea. Although it tolerates shade, it thrives better in the open, and prefers well-drained soils and an annual rainfall between 1300 and 1800 mm with a temperature of 26–35°C.

Culinary (Food) Use: The plant is a masticatory agent and is chewed in West and Central Africa as a tonic.

Ethnomedicinal Uses: The main use of Kola nuts is as a stimulant to the nervous system when chewed and as a restorative. It is an effective appetite suppressant. Kola nuts are used mainly as a masticulatory agent and as a ritual plant. An infusion of the bark mixed with ginger is administered as a treatment for stomach ulcers. In Ghana, the nuts are boiled with leaves of *Morinda lucida* and dispensed as an oral treatment for hemorrhoids. The nuts ground to a fine paste together with the leaves of *Scoparia dulcis* are dissolved in a little water and a few drops are administered orally to babies for headache. The FAO monograph indicates that the nuts, preferably the white variety, ground to a fine paste together with white clay, a little pepper, ginger, or *Piper guineense* fruits, are applied as an enema for the cure of diarrhea and dysentery.

Constituents: The plant contains purines, caffeine (about 2.5%), and small quantities of theobromine (usually about 0.025%). The plant also contains two phenolic substances, kolatin and kolatein, as well as catechols, (–)-epicatechol, and kolanin. An anthocyanin pigment called Kola red, a phlobaphen, occurs as an oxidation product of the catechols.[392,393] The plant also contains proteins (1.5%), fat (0.5%), calcium (3.1%), iron (1.4%),

vitamin A (31%), thiamine (11%), riboflavin (47%), nicotinic acid (0.7%), and ascorbic acid (9.8%)[37]; the kernel contains about 1.6% tannin.[394] It has been shown that there is a significant variation in the yield of caffeine among the different varieties and genotypes of the plant.[395]

Pharmacological Studies: Kola extracts exhibit the activities observed with caffeine, but unlike coffee, the activity is milder but persistent due to the presence of catechols and other constituents. It is a smooth muscle relaxant but produces overexcitement of the CNS, followed by depression, at very high doses. It has a tonic action on the heart by indirect effect through the nervous system and by direct effect on the heart muscles and the walls of the blood vessels. A sense of fatigue is prevented and a longer and more sustained muscular effort is encouraged. The extract is used in the preparation of several nonalcoholic beverages, and has also been incorporated into tonic wines and health foods. Kola nuts chewed at night tend to prevent sleep.

Kola extracts and the dried whole nut are ingredients in several weight loss products and dietary supplements used as instant energy boost and as antioxidants. The proanthocyanidin isolated from the related *C. acuminata* showed activity against the sleeping sickness vector *Trypanosoma brucei* and a low cytotoxicity against mammalian cells.[396]

Lemongrass

Overview

Lemongrass is culinary plant cultivated for its lemon-like fragrance. It produces a volatile oil, which consists mainly of citral, a terpene aldehyde, and geraniol, nerol, furfural, citronellal, methyleptenone, and myrcene, and the triterpenes cymbopogone and cymbopogonol. Lemongrass oil has anti-inflammatory and chemoprotective properties. The flavonoid fraction of the oil containing luteolin 7-*O*-neohesperidoside, cassiaoccidentalin B, carlinoside, cymaroside, and tannins has been formulated as potential anti-inflammatory topical agent for the treatment of skin inflammatory diseases. The tea is also hypotensive.

Pharmacognostical Profile

Botanical Name: *Cymbopogon citratus* (DC.) Stapf.

Synonyms: *Andropogon citratus*; *A. ceriferus* Heckel; *A. nardus* L. var *ceriferus* (L.) Rendle

Family: Poaceae

Common Names: Lemongrass, citronnelle (Fr.), fever grass

African Names: Bambara: ce kala; Igbo: nche awuta, ahihia tii; Turag (Arab): hhashellaymum; Yoruba: koriko oyibo, koko oba

Description: A densely tufted tall grass, usually growing up to 120 cm. Leaves grass-like, with blades tapered to both ends up to 90 cm long and 1.25 cm wide. Lemongrass seldom flowers; when it does, the flowers occur in panicles, with inflorescences of 30–60 cm long. It has a slightly bulbous base. The whole plant gives a characteristic lemon odor when broken. It is a perennial, and the propagation is from the clones.[33,37]



Habitat and Distribution: The plant requires a warm climate with plenty of sunshine. It is cultivated in Tanzania, Kenya, and the Malagasy Republic.

Culinary (Food) Use: Used as spice for soups and stews. Blended as teas. Volatile oil also edible.

Ethnomedicinal Uses: Lemongrass is used primarily as a weak infusion in the form of "teas" used for fevers and jaundice. Extracts of the plant are also dispensed as a diuretic, emmenagogue, diaphoretic, stomachic, carminative, tonic, antirheumatic, and antidiarrheal. The essential oil is used extensively in perfumery.

Constituents: Lemongrass yields up to 0.7% of volatile oil, which consists mainly of citral, a terpene aldehyde. Other constituents of the oil include geraniol, nerol, furfural, citronellal, methyleptenone, and myrcene,[397] as well as the triterpenes cymbopogone and cymbopogonol.[398,399]

Pharmacological Studies: A decoction of the leaves has been shown to possess hypotensive and diuretic effects in rats.[400] The essential oil showed antibacterial activity *in vitro*, and the activity is attributed to its geraniol and neral content.[401] The oil is believed to have a mild depressant effect on the central nervous system, and also analgesic and antipyretic activities. But recent laboratory evaluation of the plant failed to observe any effects on body temperature, gastrointestinal motility, or the central nervous system.[402] Extracts of the plant appear to be devoid of any toxicity,[403] and were not found to cause either hematological or cellular alterations, or mutagenic or embryonic toxicity.[404,405]

Locust Bean

Overview

The locust bean is obtained from the Savannah tree, *Parkia biglobosa*, and related species used in the preparation of the West African soup condiment and flavor called dawadawa. The boiled and fermented seeds contain 35% proteins, 29% lipids, and 16% carbohydrates, as well as tannins, flavonoids, and coumarins, and have good organoleptic properties

with a positive effect on intestinal flora (prebiotic). They also contains lupeol, 4-*O*-methyl-epi-gallocatechin, epi-gallocatechin, epi-catechin 3-*O*-gallate, and epi-gallocatechin 3-*O*-gallate. It has a rich pool of essential amino acids. The seeds possess antiplatelet, antioxidant, and antihypertensive activities. It has been shown to possess chemoprevention activity against different strains of human cancer cell lines.

Pharmacognostical Profile

Botanical Name: *Parkia biglobosa* (Jacq.) G.Don

Synonyms: *Inga biglobosa* (Jacq.) Willd.; *Mimosa biglobosa* Jacq.; *Parkia africana* R.Br.; *Parkia clappertoniana* Keay; *Parkia intermedia* Oliv.; *Parkia oliveri* J.F.Macbr.

Related Species: *Parkia bicolor* A Chev.

Family: *Leguminosae*

Common Names: African locust bean, nitta tree, locust bean, monkey cutlass tree

African Names: Yoruba: ewé igba, igiougba, iru; Hausa: dawadawa, daddawa; Igbo: ogiri-awusa; Fufulde (Nigeria): netteh, nerre; Mandinka (Senegal): netto; Wolof: nette, houlle, ouli; Ewe: moti, wati; Bassa: budo; Mina: woti; Malinké: néré; Baoulé: kparalé, kpalé; Fon: arouati; Peuhl: niri

Description: *Parkia biglobosa* is a medium-sized tree up to 30 m tall; taproot often present, lateral roots up to 10(–20) m spreading from the bole; the bole is usually straight and robust, cylindrical, up to 130 cm in diameter, often branching low; the bark is distinctly longitudinally fissured, often with more or less regular scales among the fissures, thick, ash-gray to grayish-brown, slash fibrous and reddish-brown, exuding an amber gum; the crown is dense, wide spreading and umbrella-shaped, consisting of heavy branches. The leaves are bipinnate, swollen at the base, and there with an orbicular gland, with 8–16 pairs of pinna; each one composed of 15–35 pairs of leaflets of 1 cm long and 2 mm broad. The inflorescence is a pendulous head arranged racemosely; the peduncle 10–35 cm long; turning salmon-pink, many-flowered. The flowers narrow, red, 3 cm long; stamens with blackish anthers. The pods are slender, a little flattened, 30 cm long. Seeds globose-ovoid and embedded in a yellowish farinaceous fleshy endocarp.



Habitat and Distribution: *Parkia biglobosa* is a Sudano-Zambezian species present in a belt between 5°N and 15°N, from the Atlantic coast in Senegal to southern Sudan and

northern Uganda. The belt is widest in West Africa (maximum 800 km) and narrows to the east. It was probably introduced to São Tomé et Príncipe.



Culinary (Food) Use: Fermented seeds of the locust bean are used as condiments to flavor soups, sauces, and stews in Africa.

Ethnomedicinal Uses: The locust bean is used in Africa as a fermented food condiment for seasoning sauces and soups. The use of the fermented beans of the African locust bean dates back many centuries and was already described in the fourteenth century. In West Africa, the bark, roots, leaves, flowers, fruits, and seeds are commonly used in traditional medicine to treat a wide diversity of complaints, both internally and externally, sometimes in combination with other medicinal plants. The bark is most important for medicinal uses, followed by the leaves. Medicinal applications include the treatment of malaria, parasitic infections, circulatory system disorders, such as arterial hypertension, and disorders of the respiratory system, digestive system hemorrhages, and dermatosis.[1] It has also been used for the treatment of measles, chickenpox, and gingivitis, and as an anthelmintic. In the Savannah and Sahel regions of West Africa, the locust bean plays a role in all major rituals, including those associated with birth, baptism, circumcision, marriage, and death.

Constituents: The boiled and fermented seeds contain 35% proteins, 29% lipids, and 16% carbohydrates and have good organoleptic properties and a positive effect on intestinal flora. The seeds are good sources of protein, fat, and calcium, but contain a nontoxic oil of variable composition. The seed fatty acids include arachidic, behenic, stearic, oleic, palmitic, and linoleic acids. The fruit pulp contains up to 80% carbohydrate. The bark was found to contain a long-chain ester of *trans*-ferulic acid, together with an inseparable mixture of long-chain *cis*-ferulates. In addition, lupeol, 4-*O*-methyl-epi-gallocatechin, epi-gallocatechin, epi-catechin 3-*O*-gallate, and epi-gallocatechin 3-*O*-gallate were isolated. The bark, leaves, and pod husks are rich in tannins, flavonoids, and coumarins.

Pharmacological Studies: The ethanolic extract of *P. biglobosa* gave a positive response in the brine shrimp lethality assay (LD_{50} 315.2 µg/mL. This result was reinforced by cytotoxicity assays against tumoral cell cultures NSCLC-N6-L16 human bronchopulmonary carcinoma, IC_{50} 13.0 50 µg/mL; KB human nasopharyngeal cancer, IC_{50} 20.0 µg/mL; P-388 leukemia in mice, IC_{50} 22.4 µg/mL.[1] The seeds possess antiplatelet,[406] antioxidant, and antihypertensive activities, and showed anti-snake venom activity.[407] The hydroalcoholic, ethyl acetate, and butanolic extracts of *Parkia biglobosa* leaf, which contained mainly procyanidins and monomeric flavonoids, induced endothelium-dependent NO- and EDHF-mediated relaxation in porcine coronary artery rings. The vasorelaxant activity is dependent on their phenolic content and appears to involve mainly procyanidins. This finding provides a probable mechanism for the antihypertensive activity of *P. biglobosa* leaves.[408]

Commerce: The fermented seeds of African locust bean, known as "soumbala," "dawadawa," "netetu," ogiri, iru, afitin, and nététou, serve primarily as a condiment for seasoning sauces and soups. Roasted seeds are used as a coffee substitute known as "Sudan coffee" or "café nègre." The extract of the stem bark is used in the preparation of a preventive medicine for cattle known as "cure salee." The African locust bean is therefore highly valued in Africa, and it is an article of trade in many parts of the continent.

Marama: Morama Bean

Overview

The marama (also called morama) bean is a protein-rich, underutilized, drought-tolerant legume in sub-Saharan Africa obtained from the southern Africa legume *Tylosema esculentum* (Burch.) Schreib. The plant is a long-lived perennial legume native to arid areas of southern Africa. Marama beans have a pleasant sweet flavor. They are comparable to roasted cashew nuts or almonds. They can be boiled or roasted, and the roasted seeds have sometimes been used as a culinary substitute for almonds. The immature seeds and stems may be eaten cooked as a vegetable or in soups. Marama has very high nutritional value with the grains having a relatively high protein content of 30%–40%. The concentration of sulfur-containing amino acids is high as well (with a lysine content of 5.0% and a methionine content of 0.7%). The protein content of the seeds is comparable to that of soybeans, which have a content of 38%–40%. Marama therefore has been considered as a possible alternative to soybean as a protein source, once there have been genetic improvements. However, the protein composition of the marama bean is very different from that of the soybean. The vicilin (7S) and the acidic 11S subunits seem to be absent in marama protein. The legumin (11S) of marama protein seems to lack disulfide bonds. The only major proteins in marama are basic legumin (11S) and two additional proteins of relatively higher molecular weight. These findings suggest that marama protein may have increased heat stability compared with soy due to strong hydrophobic interactions that are associated with the basic 11S. Since tyrosine is involved in polypeptide crosslinking, the tyrosine in marama may also contribute to the structural stability of its protein. The tubers contain about 0.9% protein and very high amino acid content.

The seed oil (25%–40% yield) is golden yellow, with a nutty odor and a pleasant, although slightly bitter, flavor, and has been described as similar to almond oil in consistency and taste. The fatty acid composition has about 75% unsaturated fatty acids, with the principal

fatty acid being oleic acid (43%), and linoleic acid (22%), and the saturated fatty acid, palmitic acid (13%). It also contains stearic, arachidic, linolenic, arachidonic, erucic, behenic, myristic, palmitoleic, and gadoleic acid in lower concentrations. The marama bean is a good source of both B vitamins and vitamin C, but a poor source of β-carotene. It contains eight vitamin E isomers and tocotrienols, as well as mineral and other macronutrients. It is rich in lignans and both secoisolariciresinol and lariciresinol were abundant even in roasted beans. Marama has a high content of polyphenols, especially flavonoids and phytoestrogens, but is not based on isoflavone moiety. The potential health benefits of marama are enormous, and include antioxidant, antimicrobial, antitumor, anti-inflammatory, antiobesity, and immune-boosting properties. As a functional food, some of its constituents are indicative of a possible role in the prevention of noncommunicable diseases such as cardiovascular diseases, diabetes, and some cancers. Owing to its high protein contents, marama bean flour could be used to increase the protein quality of cereal-based foods to help alleviate protein-energy nutrition in the continent.

Pharmacognostical Profile

Botanical Name: *Tylosema esculentum* (Burch.) Schreib

Synonyms: *Bauhinia bainesii* Schinz; *Bauhinia esculenta* Burch.

Related Species: *Tylosema fassoglense*; *T. argenteum*; *T. humifusum*; *T. angolense*

Family: Leguminosae

Common Names: Marama bean, morama bean, gemsbok bean, camel's foot

African Names: Afrikaans: moramaboontjie, elandboontjie, braaiboonjie; Tswana: marama, morama; Thonga: marumana; !Kung San: tsi, tsin; Khoi: gami; Herero: ombanui; Nama (Namibia): dz'hì, nning, nâuns; Damara/Nama (Namibia): nâu, nâuhaib, nâus

Description: Marama is a long-lived perennial, prostrate vine with numerous herbaceous stems that can be up to 6 m or longer. The marama bean is commonly found creeping over the soil surface with vines carrying double-lobed leaves that are soft and reddish brown when young, but later turn leathery and grayish-green with age. It has a tuberous root, its herbaceous or lower parts are woody, rusty hairy, with axillary forked tendrils 1–4 cm long. The leaves are alternate, simple; the stipules are 3–5 mm × 2–3 mm; the petiole 1.5–3.5 cm long; blade two-lobed for more than half its length, glabrous or pubescent beneath; lobes reniform, 3.5–5 cm × 5–6.5 cm. Typically, the pods can contain one to two seeds and are encased by a hard, water-tight coat. The seeds are ovoid to globose, 1.3–2.5 cm × 1.2–1.5 cm, reddish to brownish black. The yellow flowers, bisexual, zygomorphic, 5-merous, heterostylous; about 4 cm across, are produced in clusters of three to nine, mostly on the distal two-thirds of the stem.[4]

Habitat and Distribution: Marama grows naturally in undulating grassland (savanna) with the plant sprouting among the native grass and acacia-thorn scrub on sandy plains. It is a resilient plant that can thrive in an extreme environment with high temperatures, low rainfall (100–900 mm), and long periods of drought. It is found on sandy and limestone (including dolomite) soils, but not on soils developed over granite or basalt. The marama bean is found in grassland and wooded grassland vegetation. It occurs in localized patches. It is distributed mainly in the semiarid regions of southern Africa. It tolerates the scorching heat and long drought periods of the Kalahari Desert of Botswana and Namibia. It is also occurs in Angola, Zambia, and Mozambique. The related species *T. fassoglense* is widely distributed throughout the East African countries from Ethiopia to the northern region of South Africa and westward to Angola and northern Namibia. Beans of *T. fassoglense* are consumed in the same way as marama beans.

Culinary (Food) Use: Both the seeds and the underground tuber are important food for the indigenous populations in southern Africa, especially of the Kalahari Desert.[409] The seeds can be roasted or boiled before eating. The immature seeds of the marama bean, inclusive of seed coat, are used as vegetables. The tubers are used when no more than 2 years old. Modern application includes as a snack, cooking oil, milk, flour, and as substitute for almond and soy in assorted cuisines.

Ethnomedicinal Uses: Marama leaves and roots are employed in traditional medicine for the treatment of diarrhea and as a general tonic, subcutaneously for cellular tissue disorders. The aqueous extract of the boiled beans has been used for unspecified blood disorders (probably sickle cell anemia).

Constituents: It has a relatively high protein content of 30%–40%, comparable to that of soybeans, which have a content of 38%–40%. The concentration of sulfur-containing amino acids is high as well (with a lysine content of 5.0% and a methionine content of 0.7%). The seed oil (25%–40% yield) is golden yellow, with a fatty acid composition of about 75% unsaturated fatty acids, with the principal fatty acid being oleic acid (43%), linoleic acid (22%), and the saturated fatty acid, palmitic acid (13%). It also contains stearic, arachidic and linolenic, arachi-donic, erucic, behenic, myristic, palmitoleic, and gadoleic acid in lower concentrations.[410] Three lignans, secoisolariciresinol, lariciresinol, and pinoresinol were isolated from the marama bean. It did not seem to contain any of the potent allergens found in lupine and peanut, and it was not cyanogenic. The marama bean is a good source of both B vitamins and vitamin C, but a poor source of β-carotene. It contains eight vitamin E isomers and tocotrienols, as well as mineral and other macronutrients. It is rich in lignans and both secoisolariciresinol and lariciresinol were abundant even in roasted beans. Marama has a high content of polyphenols, especially flavonoids and phytoestrogens but not based on isoflavone moiety. A reversed-phase high-performance liquid chromatography analysis of the total phenolic acids and total flavonoids showed that the seed coat has a higher concentration of total phenolic acids and total flavonoids than the cotyledon. The phenolics detected in the cotyledon and seed coat include myricetic, kaempferol, rutin, gallic acid, protocatechuic acid, and sinapic acid.

Pharmacological Studies: The major reported biological properties of marama beans are the antioxidant and anti-inflammatory activities attributed to the high polyphenolic content. The extracts of marama seeds exhibited antimicrobial and anti-*Candida* activity at levels that were found comparable with conventional microbicidal agents.[411] It has also been shown that extractives from the husks showed minimum inhibitory quantities of 50–100 μg or no activity against *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, and *Candida albicans*. The tuber extracts were found inactive against Caco-2 and Hela cell lines, while the husk extracts showed low activity against Caco-2 and Vero cell line with IC_{50} values >400 μg/mL.[412] The ethanolic extracts of the seed coat (husk) and cotyledon, and the water extracts of the tubers were reported to exhibit high *in vitro* inhibition of rotaviruses (RV), which are a major cause of diarrhea among infants and immunocompromised individuals.[413] The probable mechanism of action of the marama cotyledon and seed coat extracts in the inhibition of the virion infectivity is through interference with replication due to accumulation of nitric oxide, since all the marama extracts used significantly enhanced nitric oxide release from H4 cells and enhanced TER (Ω/cm^2) of enterocyte barriers after coincubation with RV.

A composite of marama and sorghum in flours and porridges has been shown to possess improved nutritional quality and antioxidant activity than sorghum alone.[414] In the study, marama flours, sorghum meal, marama–sorghum composite flours, and porridges were analyzed for proximate composition, amino acid content, energy value, fatty acid

composition, total phenolic content, and antioxidant activity. Compositing sorghum meal (70%) with marama flours (30%) significantly increased the protein and fat contents in flours and porridges. Energy values of marama–sorghum composite porridges were 11%–24% higher than sorghum porridge. Lysine content was 3–4 times higher in marama–sorghum porridges than in sorghum porridge. There was an increase in oleic acid as sorghum meal was composited with marama flour. The investigators found a positive correlation between the total phenolic content and antioxidant activity in all the samples tested. The InterCEDD at Nsukka, Nigeria has also evaluated a mixture of sorghum extract, *Cajanus cajan*, and marama seeds as ready-to-use therapeutic food for children with sickle cell anemia.

Agriculture: There are five species of the genus *Tylosema* known to be growing in Africa and only *T. esculentum* and *T. fassoglense* have been domesticated to some extent. Marama is still collected from the wild, although some trial cultivations have been successful in southern Africa, Australia, the United States, and Israel. The mature seeds of the marama bean are encapsulated in hard, woody seed coats, which means that they require scarification before germination in order to increase the rate of viable seeds. Furthermore, the species of *Tylosema* are unique within the family Fabaceae for the fact that their flowers exhibit heterostyly, meaning that they are self-incompatible because of the spatial separation of the stigma and anthers.[415] This may reduce propagation potential, and obviously reduces seed production rates for cropping.[416] It has been reported that in a field experiment carried out in Texas, USA, the marama bean plant took 4.5 years to produce edible seeds, with flowering at 2 years, development of fruits or seeds at 3.5 years, and final harvesting at full maturation 1 year later.[417] The raw marama bean contains a strong trypsin inhibitor, which may reduce its culinary application and breeding experiments will include the reduction of the trypsin inhibitor as one of the desirable objectives. Processing and dietary formulations of marama beans have been used to produce oils, flours, milk, and porridges.

Marula

Overview

Marula is a medium-sized dioecious, single-stemmed tree with a wide spreading crown. It is indigenous to the miombo woodlands of southern Africa, the Sudano-Sahelian range of West Africa, and Madagascar. The fruits are succulent and tart with a strong and distinctive flavor. The plant contains flavonoids, catechins, and gallotannins. The pulp and kernels of the fruit contain glucosides, amino acids, and lipids (mostly oleic [60%], myristic, and stearic acid). The fruits are rich in vitamin C, containing about 8 times the vitamin C in oranges. The fruit is used to make the cream liqueur Amarula, sold as a frozen puree used in juice blends. Marula oil is used as an ingredient in cosmetics. *Sclerocarya* extracts have been shown to possess significant biological activities, including antidiabetic, anti-inflammatory, antioxidant, *in vitro* inhibition of *Helicobacter pylori*, and for the management of elevated blood pressure.

Pharmacognostical Profile

Botanical Name: *Sclerocarya birrea* (A. Rich.) Hochdst
Synonyms: *Spondias birrea* A. Rich.; *Poupartia birrea* (A. Rich.) Aubrev.

Family: Anacardiaceae
Common Name: Marula fruit, daniya
African Names: Bambara: N' guna; Boran: didissa; Dugbani: mu-mugga; Issala: burunogo; Hausa: daniya, huli, nunu; Nankani: nanogba; Sebei: katetalam; Shona: muganu, mufura, ikanyi; Sonrai: diney; Swahili: mugongo; Tamacheck: tuwila; Wolof: birr; Zulu: umganu
Description: A tall tree about 14 m high and up to 1 m in diameter. It is a light gray, finely fissured and flaking in small or large scales; slash orange pink with green edges, fibrous, exuding a nearly colorless gum; a short bole and stout branchlets. The leaves have a slender glabrous common stalk 10–22 cm long, compound, alternate, tufted at the ends of the branchlets. The leaflets are opposite or nearly opposite, 5–10 pairs with an off-terminal leaflet, elliptic to obovate, 2–5 cm wide, apex more or less rounded but with a very short, sharp tip, base cuneate, margins usually entire, dentate on young and coppice undergrowth, glaucous, pale green, venation obscure, subsessile. The flowers appear when the tree is leafless, dioecious, greenish-white or reddish; subtending bracts reddish, broadly ovate, conspicuous at first. The male flowers have 12 or more stamens and occur as solitary, erect spikes; the female flowers occur two or three together, the pedicels are stout, 2–2.5 long, the sepals are purple-red. The petals are recurved, green with purple-red tips. The fruit occurs as a pale yellow drupe, subglobose, 3–4 cm long, 2.5–3.5 cm in diameter, containing 2–3 seeds surrounded by a leathery rind and fibrous pulp.[1]



Habitat and Distribution: The plant occurs in the drier savannas of northern tropical Africa, usually on sandy soils and sometimes on lateritic or stony soils. It can thrive in areas with rainfall as low as 300 mm per annum; in higher rainfall areas, 450–800 mm, the tree is often conspicuous, an emergent tree through the canopy of the neighboring savanna trees. It is distributed in the savanna belt between Senegal and Ethiopia, and drier areas of southern Africa. It has been located in Togo, Mali, Guinea Bissau, Gambia, Ivory Coast, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Chad, Sudan, and Uganda.
Culinary (Food) Use: Marula fruits are highly aromatic and can be eaten fresh or used in making juices, jams, and alcoholic beverages, such as marula liqueur and tombo.
Ethnomedicinal Uses: The main use of the plant in traditional medicine is for the treatment of diabetes. The Hausas use a cold infusion of the stem bark for the treatment of

dysentery. And in Senegal, the leaves and root barks are employed with other plants in the preparation of a plaster as a remedy against snake and scorpion bites. An infusion of the bark is used to wash infants as a treatment for malaria or inflammation.[418] The east and southern African species *S. caffra* Sond is employed extensively in traditional medicine, and has been used for the treatment of dysentery and diarrhea, malaria, and as a general tonic. The latter species is administered by the Venda, in the form of powdered bark for expectant mothers to regulate the sex of the child: bark from a male tree is dispensed for a boy and bark from a female tree for a girl. The plant is used in religious rituals by the Shagana as a divination dice. Both species yield pleasant-tasting fruits that are often fermented to produce a refreshing drink.[1]

Constituents: The plant has been shown to contain flavonoids, catechins, and gallotannins. The pulp and kernels of the fruit contain glucosides, amino acids (especially glutamic acid and arginine), and lipids (mostly oleic [60%], myristic, and stearic acid). The fruits are rich in vitamin C, containing about 8 times the vitamin C in oranges. The nutritional profile of the pit has been evaluated and it contained relatively large amounts of copper (24.8 mg/g dry weight), magnesium (4210 mg/g dry weight), and zinc (62.4 mg/g dry weight). The protein content of the pit was high (36.4% of dry weight); however, the protein fraction contained relatively low proportions of leucine, phenylalanine, lysine, and threonine. Fatty acids accounted for 47 mg/g dry weight of the pit, two-thirds of which was due to oleic acid. The essential fatty acid linoleic acid was present (24.5 mg/g dry weight), but the other essential fatty acid, α-linolenic acid, was absent.[1]

Pharmacological Studies: The extract of the plant has been shown to possess hypoglycemic action following intraperitoneal or oral administration.[419–421] The activity is believed to include peripheral stimulation of glucose uptake and metabolism. The anti-inflammatory effects of the aqueous and methanolic stem bark extracts (500 mg/kg p.o.) have been examined on rat paw edema induced by subplantar injections of fresh egg albumin (0.5 mL/kg). Acetylsalicylic acid (ASA, 100 mg/kg p.o.) was used as the reference anti-inflammatory agent for comparison. Both the aqueous and methanolic stem-bark extracts of *S. birrea* (500 mg/kg p.o.) progressively and time-dependently reduced rat paw edema induced by subplantar injections of fresh egg albumin. However, the methanolic extract of the plant produced relatively greater and more pronounced anti-inflammatory effect than its aqueous extract counterpart in the experimental animal model used. The two extracts of *S. birrea* stem bark were found to be markedly less potent than ASA as an anti-inflammatory agent.[422]

Various extracts (crude decoction, aqueous, ethanolic, and chloroformic extracts) showed significant antagonistic effect on caffeine-induced calcium release from the sarcoplasmic reticulum. The crude decoction was the most active followed by ethanolic, aqueous, and chloroformic extracts in a dose-dependent manner.[423] Other activities found with *Sclerocarya* extracts include *in vitro* inhibition of *Helicobacter pylori*, antioxidant, and for the management of elevated blood pressure.

Commerce and Agriculture: Although Marula is not a well-known agricultural crop outside Africa, it belongs to the same family Anacardiaceae as mango, cashew, pistachio, and sumac, which makes its cultivation and commerce manageable when tailored along the tested routes of other members of the plant family. The fruits that ripen between December and March are collected from the wild by members of rural communities on whose land the trees grow. This harvest and sale of fruit only occurs for 2–3 months but is an important income to poor rural people. The fruit is delivered to processing plants where fruit pulp, pips, kernels, and kernel oil are extracted and stored for processing throughout the year.[424]

Mondia: White's Ginger

Overview

Mondia whitei is a perennial, woody, rather robust and vigorous climber indigenous to most parts of sub-Saharan Africa, where it has a reputation as an effective aphrodisiac and is used in traditional medicine for the treatment of male sexual dysfunction. *Mondia* is rich in minerals, vitamins, and other nutrients. It elaborates a mixture of triterpenes, flavonoids, reducing sugars, and tannins. The plant contains a potent tyrosinase inhibitor, 2-hydroxy-4-methoxybenzaldehyde, (–)-loliolide, isovanillin, coumarins, and coumarinolignan as well as chlorinated coumarinolignan. The aphrodisiac property of the plant has been demonstrated in several studies. It has antioxidant, anti-inflammatory, and mild antidepressant properties. *Mondia* is traded throughout the continent and harvested from the wild, which has serious conservation implications for this useful species.

Pharmacognostical Profile

Botanical Name: *Mondia whitei* (Hook.f.) Skeels
Synonym: *Chlorocodon whitei* Hook.f.
Related Species: *Mondia ecornuta* (N.E. Br.) Bullock
Family: Apocynaceae
Common Names: White's ginger, tonic root (Eng.)
African Names: Angola: mundondo, mudondo; Cissongo (Central African Republic): mundondo, bondo, molo busio; Ngwaka (DRC): nlondo, kimbiolongwa, kumba; Lugware (DRC): ubasangbwandiya, gatimba; Tshiluba (DRC) mujimbaye; Fula (Guinea, Guinea Bissau): lacadje; Kenya: mkombela; Malawi: citumbulo; Zulu: umondi, mundi, mindi; Uganda: sedando omutona; Shona (Zimbabwe): mungurawu.

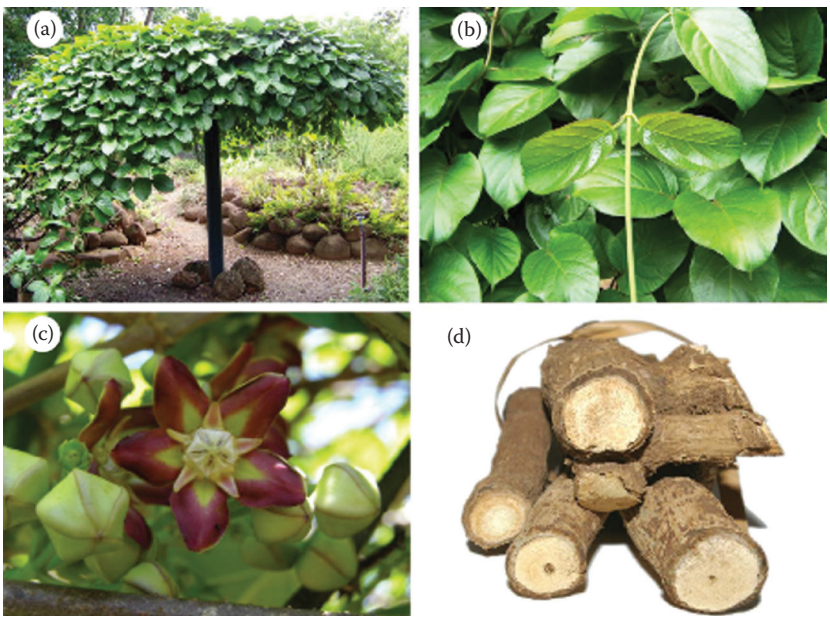
Description: According to a description provided by the South Africa National Biodiversity Institute, *Mondia whitei* is a perennial, woody, rather robust and vigorous climber that grows from a large tuberous rootstock. The roots are aromatic and apparently taste like ginger or licorice and have an aroma reminding one of vanilla. The leaves are attractive, large (100–300 × 50–150 mm), opposite, with a deeply notched heart-shaped base and 30–55 mm long stalks. The stipules are well developed and consist of frilly teeth. The flowers are borne in branched inflorescences. They are large and relatively short-lived (die after 3–4 days). The reddish purple corolla lobes are ±14 mm long and usually have a green margin. Plants flower from October to March in the southern distribution area of the species, and from May to August in the northern distribution area of the species. The large fruits (75–100 × 44 mm) are almost woody and contain many seeds.[425] Because the plant grows as a climber with the basal portion of the stem usually leafless, the leaves and flowers mainly appear in the canopy of the supporting vegetation and are thus rarely noticed.

Habitat and Distribution: *M. whitei* is native to Africa and it is considered endemic in almost all African regions with the exception of the northern part of the continent. *Mondia* occurs mainly in moist to wet forests. It is found in vegetation types that range from swamp forest, swampy shrubby grassland, and riverine forest to disturbed forest, at altitudes from sea level to 1800 m. In West Africa, the species is commonly found in Guinea, Ghana, and Nigeria; in the Central Africa region, it occurs in Cameroon, Gabon, and DRC; in East Africa, it is found in Kenya, Tanzania, and Uganda; and in southern Africa, it occurs in South Africa, Malawi, Angola, Mozambique, and Zimbabwe.

Culinary (Food) Uses: *Mondia* roots have a slightly bitter taste at first but a sweet aftertaste and a pleasant vanilla odor. They are used to make a tonic beverage similar to ginger beer. The young roots are sweet in taste and are less valued.

Ethnomedicinal Uses: *Mondia* is used as an appetite stimulant and in the treatment of indigestion, anorexia, and stress. In West Africa, the roots are brewed in alcohol and used to make an energizing drink for wedding parties. *Mondia* can be used as a tea. The plant is reputed to be an effective aphrodisiac and is valued as a medicine for the treatment of chronic male sexual erectile dysfunction and impotence. It has been used as a general anodyne and for the treatment of hypertension, stroke, anemia, asthma, hangover, mastitis, and allergies; it is also taken to improve sleep, enhance urination, ease birth pains, and as a mouth freshener and toothbrush, and for the treatment of fits in children.

Constituents: The plant has been shown to contain a potent tyrosinase inhibitor 2-hydroxy-4-methoxybenzaldehyde, (–)-loliolide, isovanillin, coumarins, and coumarinolignan as well as chlorinated coumarinolignan. *Mondia* elaborates a mixture of triterpenes, flavonoids, reducing sugars, and tannins. Nutritional analysis indicates that *Mondia* is rich in minerals and vitamins. The yields of the various nutrients (roots) and (leaves) are as follows (mg/g): potassium (11.34, 32.05), sodium (5.61, 24), magnesium (1.40, 2.83), calcium (3.08 8.25), iron (0.20, 0.43), zinc (0.03, 0.07), copper (0.003, 0.06), manganese (0.64, 0.05), cadmium and lead (trace, trace), crude protein (4.35, 21.8), β-carotene (0.004, 0.022), thiamine (0.78, 3.70), niacin (0.52, 8.15), riboflavin (0.62, 2.45), fructose (0.008, 0.015), xylose (9.17, 18.70), and glucose (2.40, 9.0).



Mondia whitei (a) creeping and well supported on an iron bar; (b) twining stems with leaves; (c) young buds and fully opened flowers; and (d) mature roots. (Adapted from Aremu, A. O. et al. 2011. *South Afr J Bot* 77: 960.)

Pharmacological Studies: Some of the biological activities associated with *Mondia* have been evaluated in a number of scientific studies to validate some of the traditional

uses. The studies include biological assays on the aphrodisiac, antimicrobial, anti-inflammatory, antityrosinase, and antioxidant activities. The aphrodisiac efficacy of *M. whitei* roots has been established in various animal studies.[427,428] The extracts displayed significant inhibition of tyrosinase and this property could account for its observed cytotoxicity against certain types of cancer *in vitro*. The methanol extract has also been shown to possess *in vitro* antioxidant activity[429] and anti-inflammatory property as evidenced by the remarkable inhibition (>80%) of cyclooxygenase-1 (COX-1) enzyme.[430] The ethanol leaf extract showed moderate antidepressant activity *in vitro* in the serotonin reuptake transport (SERT) assay.[431] Bioguided isolation identified the presence of (–)-loliolide in the active fraction with IC_{50} of 977 μM. The extract had significant *in vivo* activity in both the tail suspension test (TST) and forced swim test (FST), and locomotor activity tests.[432]

Commerce: *Mondia* is widely traded in most parts of the continent for its aphrodisiac properties and the treatment of male erectile dysfunction. Because it is not usually traded across borders, not much information is available on the volume of trade or harvest of the species. The fresh roots are sold for US$ 7–12 per kg. In East Africa, the wholesale price for the whole plant is US$ 0.20–0.30 per kg and retails for more than US$ 2 per kg. In Nigeria, small pieces (0.01–0.02 m in diameter and up to 0.4 m in length) of the root are sold by street vendors for US$ 0.20 each.

Agriculture: This species is easily cultivated from seed. Seeds are collected as the fruit starts to split open; they are picked off from their parachute-like tuft of hairs before it opens. The seeds are best sown fresh, but they can be stored for about a year under normal room conditions. Wood-ash from a fire is mixed with the seed to prevent attack by insects. The plant is however largely harvested from the wild. The root is the plant part used most in traditional medicine, and studies on *M. whitei* have also focused on the root/root bark extracts, which is an indication of the high stress on the underground plant part. The plant is seriously threatened by overharvesting. There have been proposals on the possibility of sustainable harvesting of the species from the wild.

Moringa: Horseradish Tree

Overview

Moringa is one of the most popular dietary supplements in Africa and it is being increasingly recognized by the rest of the world as a nutrient-rich superfood. The leaves contain amino acids, including aspartic acid, glutamic acid, serine, glycine, threonine, α-alanine, valine, leucine, isoleucine, histidine, lysine, cysteine, methionine, arginine, and tryptophan. The flowers and the fruits also contain amino acids. The seeds yield an almost colorless fixed oil, known in commerce as *Beni* or *Moringa* oil. The oil consists of a 60% liquid olein fraction and 40% solid fat. The major constituents of the oil are oleic acid (65%), stearic acid (10.8%), behenic acid (8.9%), myristic acid (7.3%), palmitic acid (4.2%), and lignoacetic acid (3.0%).[433] *Moringa* has remarkable antioxidant, anti-inflammatory, and immunomodulatory activities. It has been shown to have chemoprotective and antifertility properties. *Moringa* should be regarded as consisting of three distinct herbs: the highly nutritional leaves, the seeds, and the aerial parts. There are many scientific and clinical evidence to support the use of the leaves as dietary supplements for the treatment of hyperlipidemia, hypertension, and diabetes, diseases due to oxidative stress, anemia, and chronic arthritis.

Pharmacognostical Profile

Botanical Name: *Moringa oleifera* Lam.

Synonyms: *M. pterogosperma* Gaerthn.; *Hyperanthera moringa* (L.) Vahl.; *Guilandina moringa* L.

Family: Moringaceae

Common Names: Oil of Ben tree, horseradish tree, Drumstick, Ben aile' (French)

African Names: Arabic: habbah ghaliah; Ewe: babatsi; Hausa: zongallagandi, danga; Igbo: okwe-beke (okwe-oyibo); Yoruba: ewe igbale

Description: A small deciduous tree of about 8 m high, with pale gray bark and soft wood. It has a crooked stem that is often forked near the base. The twigs and young shoots are densely hairy. The leaves are tripinnate, usually with six pairs of pinnae, large, and alternately arranged on the stem. Secondary and tertiary leaflets are oppositely arranged, dark green above and pale green below the surface, with variable shapes and sizes but mostly obovate. The flowers are small, sweet-scented, and borne on loose axillary common stalks up to 15 cm long, cream-colored, with unequal petals that are usually larger than the sepals; the latter are five, pale green, up to 1.2 cm long, and finely hairy. The fruits are three-angled, pod-like, up to 45 cm long and 1.3 cm broad, slightly constricted at intervals, gradually tapering to a tip, containing rows of blackish, rounded, oily seeds, each of which has three papery wings.



Habitat and Distribution: It is a tropical plant, cultivated in most parts of the continent but probably native to Morocco, Egypt, and Tunisia.

Culinary (Food) Use: *Moringa* leaves and young pods are used as vegetables and added to soups and salads to aid digestion and to stimulate appetite.

Ethnomedicinal Uses: The infusion of the root bark is dispensed for venereal infections and the treatment of fevers. The kernel yields a clear, sweet oil that is applied externally as a counterirritant like mustard. The pounded root mixed with salt is used as poultice for inflammatory swellings. The tree is planted on graves to keep away hyenas and its branches are used in the preparation of a charm against witches. The seeds are used in Sudan and other parts of North Africa for water purification. In East Africa, the seeds are used in the induction of abortion.

In India, the root is used as a stimulant in paralytic syndrome and for the treatment of epilepsy, nervous disorders, hysteria, and spasmolysis, as well as a cardiac circulatory tonic.[3] In India, the plant is cited for the treatment of diseases of the liver, spleen, and articular pains; the tender leaves are indicated for scurvy and catarrh, and given to children suffering from flatulence.[3]

Constituents: The leaves are rich in amino acids, including aspartic acid, glutamic acid, serine, glycine, threonine, α-alanine, valine, leucine, isoleucine, histidine, lysine, cysteine, methionine, arginine, and trptophan.[434] The flowers and the fruits also contain amino acids.[435] The root bark yields the sulfureted amino bases moringinine and spirochine, as well as benzylamine and glucotropaeline. The seeds contain an almost colorless fixed oil, known in commerce as *Beni* or *Moringa* oil. The oil consists of a 60% liquid olein fraction and 40% solid fat. The major constituents of the oil are oleic acid (65%), stearic acid (10.8%), behenic acid (8.9%), myristic acid (7.3%), palmitic acid (4.2%), and lignoacetic acid (3.0%).[433] The stem bark has been shown to contain sterols and terpenes,[436] as well as 4-hydroxymellin, vanillin, β-sitosterol, β-sitosterone, and octacosanoic acid.[437] The roasted seeds contain 4-α-L-rhamnosyloxyphenyl acetonitrile and 4-hydroxyphenyl acetamide.[438]

Pharmacological Studies: The juice from the leaves and stem bark showed antibacterial and antitubercular activity,[439,440] and root bark extract showed antiviral effect against vaccinia virus,[441] and anti-inflammatory and analgesic activity.[598,599] Ethanol extract of the whole plant demonstrated significant cytotoxic activity against human epidermoid carcinoma of the nasopharynx in tissue culture and *in vivo* activity against P_{388} leukemia in mice.[442] Moringinine has been shown to exhibit a sympathomimetic activity similar to that of adrenalin. The compound has cardiac stimulant activity, as well as peripheral vasoconstriction and elevation of blood pressure. It has a depressive action on smooth muscle fibers, relaxes the bronchioles, and inhibits the tone and movement of the intestine in rabbits and guinea pigs.[443]

Two complex benzylisothiocyanates found in the root, pterospermine and anthomine, possess strong antimicrobial activity; the latter is also active against *Vibrio cholerae*. Spirochine at a dose of 0.035 g/kg accelerates and amplifies the heartbeat in humans, and at an elevated dose of 0.35 g/kg, the compound exhibits an opposite effect. The compound produces generalized paralysis of the CNS and also possesses antimicrobial activity.[444]

The plant has remarkable antifertility properties. The oral administration of an aqueous extract of the root has estrogenic, antiestrogenic, progestational, and antiprogestational effects.[445] It was shown that the extract progressively increased the uterine wet weight of bilaterally ovariectomized rats. The estrogenic activity was supported by stimulation of uterine histoarchitecture. In 50% of the rats tested, a dose of 600 mg/kg of the extract interfered with the formation of deciduoma, which is indicative of antiprogestational activity, although the same dose failed to induce a decidual response in the traumatized uterus of ovariectomized rats. The treatment of rats with the extract caused an enlargement of the lumen, and the luminal epithelium remained unstimulated; the uterus was nondematous; in the control group, glandular cells showed hypertrophy and in the endometrium, the leukocytic infiltration was increased. The antifertility activity of the plant could therefore be due to the nonreceptive state of the uterus throughout the treatment period.[446] The biochemical and physiological alterations in the genital tract of female cyclic rats following the administration of an aqueous extract of the plant have been investigated. It was observed that after administration of the drug, there was an initial stimulation of the uterine structures, metaplasmic changes in the cervical epithelium, and considerable cornification in the vaginal epithelium was provoked. These effects were followed later by significant inhibition in the histoarchitecture and changes in some biochemical parameters.[447]

The aqueous extract of the seeds, which is used for water purification in Sudan, has been shown to effect a turbidity reduction of 80%–90.5% and concomitant reduction in the bacterial count after 1–2 h of treatment, with the bacteria being concentrated in the coagulated sediment.[448] *Moringa* should be regarded as consisting of three distinct herbs: the highly nutritional leaves, the seeds, and the aerial parts.

There are many scientific and clinical studies that have provided much evidence to support the use of the leaves as dietary supplements for the treatment of hyperlipidemia, hypertension, diabetes, diseases due to oxidative stress, anemia, and chronic arthritis. A traditional herbal formulation that contains *Moringa oleifera* leaves, *Bidens pilosa*, and sodium chloride is used in Côte d'Ivoire for the treatment of high blood pressure with positive results. The herbal supplement (HS) at doses of 5×10^{-8}–5×10^{-2} mg/kg caused a dose-dependent hypotension. HS elicited drops in blood pressure ranging between $7.14 \pm 4\%$ and $100 \pm 7.5\%$, compared to the normal blood pressure of rabbits. Fifty percent effective dose of HS was 3.95×10^{-4} mg/kg, which was similar to the hypotension induced by acetylcholine, the one caused by HS at a dose of 3.95×10^{-4} mg/kg in rabbit was progressively inhibited by atropine, dosed between 5×10^{-4} and 5×10^{-2} mg/kg. The percentage drop of recorded blood pressure ranged from 50.3 ± 1.87 to $3.71 \pm 1.09\%$ compared to the normal value of blood pressure. In the presence of atropine, the HS effect was partially inhibited. The same increasing doses of HS significantly reduced the increase of blood pressure induced by adrenaline dosed at 4.76×10^{-4} mg/kg from $89.3 \pm 2.19\%$ to $1.19 \pm 0.59\%$.[600]

Myrrh

Overview

Myrrh is the oleo-gum-resin obtained from several species of the genus *Commophora*. Two varieties of myrrh are known in commerce, the oily "guban" myrrh and the more powdery "ogo" variety. The oleoresin is collected as exudates from fissures or incisions in the bark, which dries in the collecting vessels as irregular masses or tears. It contains arabinose, galactose, 4-*O*-methylglucuronic acid, and xylose, as well as eugenol, cadinene, furanodiene, furanosesquiterpenes, heerabolene, cuminaldehyde, and elemol. Myrrh has been shown to possess significant antioxidant and anti-inflammatory activity.

Pharmacognostical Profile

Botanical Name: *Commiphora molmol* Engl.

Synonyms: *C. hildbrandtii*; *C. serrulata*; *C. rivae*; *C. cuspidate*; *C. coriacea*; *Balsamea myrrha* (T.Nees) Oken; *Balsamea myrrha* Baill.; *Balsamodendrum myrrha* T.Nees

Family: Burseraceae

Common Names: Myrrh, oleo-resine (Fr.), molmol

African Names: Arabic: morrh; Hausa: dashi, 'biskiti; Yoruba: turari; Swahili: mbebe, mbele

Description: Myrrh is obtained from several *Commiphora* species, especially *C. molmol* Engl., *C. abyssinica* (Berg.) Engl., and *C. mukul* Hook ex Stocks. The drug, also known as Somalian or Arabian myrrh, is collected from wild trees of *C. molmol* in Somalia and parts of northeast Africa and Arabia. Two varieties of myrrh are known in commerce, the "guban" myrrh, which is rather oily, and the more powdery "ogo." The oleoresin is collected as exudates from fissures or incisions in the bark, which dries in the collecting vessels as irregular masses or tears. It has a somewhat reddish-yellow color turning slightly brownish with time. It is dotted with whitish marks and has thin translucent splinters. It has a bitter but pleasant taste and aromatic odor. Guggal resin, or gum, is obtained from *C. mukul* and referred to sometimes as *guggulu*.

Habitat and Distribution: Various species of the genus grow in the arid and tropical regions of the continent. Somalia is the natural habitat of the plant but it is also cultivated in Kenya, Tanzania, Ethiopia, and some North African countries.

Culinary (Food) Uses: Myhrrh is edible and used as a digestive aid.

Ethnomedicinal Uses: It is employed as a mouthwash and gargle for the treatment and prevention of oral infections. It is also used as a stimulant and emmenagogue. A decoction of the stem bark is used by the Masai as a purgative, and by the Nyamwezi as a snake bite remedy. In East Africa, various species of the genus *Commiphora* are used for wound dressing and for indigestion. The stem bark of *C. Africa* is used in Niger Republic as an oral treatment for various diseases.[449] In West Africa, vapor from the gum resin in boiling water is used for the treatment of eye inflammation and the bark is applied as a remedy for scorpion bite.

Constituents: Myrrh consists of about 60% gums, which are usually composed of arabinose, galactose, 4-*O*-methylglucuronic acid, and xylose.[450] Other constituents, eugenol, cadinene, furanodiene, furanosesquiterpenes, heerabolene, cuminaldehyde, and elemol, are found in the volatile components.[451] The resinous fraction is about 30% of the total weight and contains commiferin, α-, β-, and γ-commiphoric acid, α- and β-heerambomyrrhols, commiphorinic acid, and heeraboresene. It also contains sterols and proteins.[452]

Pharmacological Studies: The petroleum ether extract of myrrh, at a dose of 500 mg/kg body weight, has been shown to produce significant inhibition of carrageenan-induced inflammation and cotton pellet granuloma.[453] It also showed significant antipyretic activity in mice. Myrrh has been found to inhibit the growth of microorganisms in *in vitro* assay.[454]

The oleoresin from *C. mukul*, *guggulu* gum, inhibits platelet aggregation and increases catecholamine biosynthesis and activity in cholesterol-fed rabbits.[455,456] It is also hypolipidemic and hypocholesterolemic in both humans and animals.[457] Guggulu resin has been found to activate the thyroid glands in chickens and rats.[458] It has also been reported to have significant anti-inflammatory and antiarthritic activity.[459] The anti-inflammatory activity of *C. mukul* oleoresin has been associated with the presence of steroids such as E- and Z-guggulsterone, the Z-guggulsterols.[460] The volatile oil contains cembrene A in addition to other constituents found in the volatile oil of *C. molmol.* Delaveau has reported that the extracts of *C. abyssinica* stimulate phagocytosis in mice inoculated with *E. coli*.[601]

Clinical Applications: Myrrh is an ingredient in mouthwashes because of its antiseptic and stimulant properties. It is used in folk medicine as an expectorant, anti-inflammatory, and antispasmodic and for the treatment of orodental infections. The crude drug is sold throughout north and eastern Africa and in Saudi Arabia as a remedy for inflammatory conditions and rheumatism.

Nutmeg Tree

Overview

Nutmeg is used as a spice for cooking. It contains about 10% of volatile oil comprising linene and camphene as the major constituents, and the minor constituents include myristicin, safrole, elemicin, terpeneol, cymene, α-thujene, γ-terpinene, linalool, eugenol, isoeugenol, methyleugenol, and several minor terpenoids. It is a mild hypnotic and a prostaglandin synthetase inhibitor.

Pharmacognostical Profile

Botanical Name: *Myristica fragrans* Houtt.

Synonyms: *M. moschata.*; *M. officinalis* L.

Family: Myristiaceae

Common Names: Nutmeg tree, Muscadier (Fr.).

African Names: Arabic: goz el-tieb; Igbo: ehuru; Swahili; kungu; Yoruba: abolakose, ariwo

Description: Nutmeg is the dried kernel of the seed while mace is the dried outer covering or aril. *Myristica fragrans* is a dioecious evergreen tree, growing up to 60 ft but most are about 40 ft high, with grayish-black bark, which are longitudinally fissured in old trees. The leaves are elliptic or oblong-lanceolate, coriaceous, and the flowers occur as umbellate cymes. The yellow fruits, with fleshy pericarp, are 6–9 cm long, glabrous, and usually drooping. The seeds are pale brown, about 3 cm long and 2 cm broad, with a reticulate surface patterned with grooves, lines, and specks. The seed has a characteristic aromatic odor and bitter aromatic taste.

Habitat and Distribution: It grows in humid tropical forest regions, and is widely cultivated throughout the continent.

Culinary (Food) Use: Nutmeg is used as a spice and flavoring agent for soups and other cuisines.

Ethnomedicinal Uses: The essential oil is used as a carminative and applied externally for rheumatism.[1] It is used in soaps as a postpartum medication.

Constituents: Nutmeg contains about 10% of volatile oil comprising linene and camphene as the major constituents, and the minor constituents include myristicin, safrole, elemicin, terpeneol, cymene, α-thujene, γ-terpinene, linalool, eugenol, isoeugenol, methyleugenol, and several minor terpenoids. The plant also yields up to 40% of fixed oil, proteins, and diarypropanoids, as well as elimicin and safrol.[461]

Pharmacological Studies: The drug is a mild hypnotic agent, and the component responsible for this activity is myristicin. The drug is an inhibitor of prostaglandins and related endochemicals produced by the human colon,[462–464] and has also been found to decrease prostaglandin levels in rats.[465] It has carminative, spasmolytic, antiemetic, and/or oxygenic activity, and has been used clinically for the treatment of a variety of stomach disorders, including nausea, flatulence, indigestion, and diarrhea, especially diarrhea secondary to thyroid medullary carcinoma. The drug has platelet aggregation inhibition activity associated with the eugenol and isoeugenol content.[466] The hypnotic effect does not appear to be manifest when nutmeg is used as a culinary spice.

Toxicology: High doses of nutmeg are highly hypnotic and toxic. Reported adverse effects include hypothermia, giddiness, nausea, weak pulse, and a general feeling of heaviness in the chest and lower abdomen.[1] It also causes tachycardia, and the oil decreases fertility in rats.[467] One of the constituents of nutmeg, safrole, has been found to be carcinogenic in mice.[468]

Okra

Overview

Okra or okro is a fruitlike vegetable used alone or in soups and sauces throughout the continent. The "common okra" (*Abelmoschus esculentus* (L.) Moench) is cultivated widely in Africa, Asia, and South America, whereas its close relative, the West African okra (*Abelmoschus caillei* (A.Chev.) Stevels) is restricted to the humid and perhumid climates of

Africa. No significant difference has been reported between the two species. Okra possesses strong antioxidant, anticholesterolemic, antidiabetic, and significant α-amylase and α-glucosidase inhibitory properties. Studies have shown that it alleviates renal tubular–interstitial diseases, improves renal function, and reduces proteinuria. It has been used as a blood plasma replacement or blood volume expander. The fruits are rich in essential nutrients and fiber. It contains polysaccharides, proanthocyanidins, (epi) gallocatechins, and (epi) catechins. The seeds contain about 20% protein with an amino acid composition that is similar to that of soybean protein. It yields about 20% oil that has a fatty acid profile that resembles cottonseed oil. Roasted okra seeds have been used as a coffee substitute and it was useful in the management of depression.

Pharmacognostical Profile

Botanical Name: *Abelmoschus esculentus* (L.) Moench

Synonyms: *Hibiscus esculentus* L.; *Abelmoschus bammia* Webb; *Abelmoschus officinalis*; *Abelmoschus longifolius* (Willd.) Kostel.; *Abelmoschus praecox* Sickenb; *Abelmoschus tuberculatus*

Related Species: *Abelmoschus manihot* (L.) Medik *Synonym: A. caillei* (A.Chev.) Stevels; *A. pseudomanihot* DC. Endl; *A. platidactylus* (Bakh.) Nakai; *Hibiscus manihot*; *Hibiscus papyriferus* Salisb.

Family: Malvaceae

Common Name: Common okra, okro, okra, lady's finger, ladies finger, gumbo

African Names: Akan (Twi): nkruman, nkruma (okra); Bantu: ki ngombo, ngumbo, gombo; Congo, Angola: quillobo, ki ngombo; Swahili: gumbo; Igbo: okwuru

Description: Okra is a stout annual herb typically reaching 2 m in height, but some African varieties may grow up to 5 m tall, with a base stem of 10 cm in diameter. The heart-shaped, lobed leaves are attached to the thick woody stem. They may reach 30 cm in length and are generally hairy. Flowers are borne singly in the leaf axils and are usually yellow with a dark red or purple base. Some of the African varieties bloom only in late fall in temperate zones and are photoperiod sensitive. It is largely self-pollinated, though some out-crossing is reported and it is often visited by bees.

The pod (capsule or fruit) is 10–25 cm long (shorter in the dwarf varieties). Generally, it is ribbed or round, and varying in color from yellow to red to green. It is pointed at the apex, hairy at the base, and tapered toward the tip. It contains numerous oval seeds that are about the size of peppercorns, white when immature and dark green to gray-black when mature.[5]



Habitat and Distribution: The genus *Abelmoschus* is believed to have originated in South-East Asia. The common okra, *Abelmoschus esculentus*, however, is a cultigen of

uncertain origin. The vast occurrence of primitive types and wild relatives in Africa (especially Ethiopia, Nigeria, Cameroon, and Ghana) indicates that okra is certainly African. It is however widespread in tropical, subtropical, and warm temperate regions, but is particularly popular in West Africa, India, the Philippines, Thailand, and Brazil. The common okra grows in the whole of tropical Africa, whereas West African okra, *Abelmoschus manihot* (L.) Medik, is a cultigen occurring mainly in West and Central Africa. It has been reported from Guinea to Nigeria in West Africa, Cameroon, Gabon, and DR Congo in Central Africa, and Uganda in East Africa. Its distribution is restricted to humid and perhumid climates in Africa, between 12°N and 12°S, most commonly between 5°N and 10°N, whereas the common okra can be found worldwide throughout the tropics, subtropics, and warm temperate regions.

Culinary (Food) Use: Okra is used either raw or cooked as a vegetable. It is a major ingredient in the West African slimy sauce or draw soup. The seeds are also edible. Young leaves are used in vegetable soups as spinach.

Ethnomedicinal Uses: The immature fruits and the leaves are eaten in various ways. Fruits, fresh or sliced and dried, are used for soups (West African draw soup); and are also fried in oil. Leaves are used as a potherb. Young shoots are also eaten. The mucilage is used medicinally and technically as an industrial raw material. A decoction of the immature okra fruits is demulcent, diuretic, and emollient. It is also used in the treatment of catarrhal infections, *ardor urinae*, dysuria, and gonorrhea. It has been used as a plasma replacement or blood volume expander. The seeds usually obtained from mature and hard capsules are antispasmodic, cordial, and stimulant. An infusion of the roasted seeds has sudorific properties. Leaves are sometimes used as a basis for poultices, as an emollient, sudorific, or antiscorbutic, and to treat dysuria.

Constituents: All the aerial parts of the plant are useful although the ends of the fruits are usually trimmed off leaving about 80% of the product as the edible portion. The composition of okra fruits per 100 g edible portion is water 88.6 g (85.7–90.2), energy 144 kJ (36 kcal), protein 2.1 g (1.1–3.0), fat 0.2 g, carbohydrate 8.2 g, fiber 1.7 g, Ca 84 mg (55–142), P 90 mg, Fe 1.2 mg (1.1–1.5), β-carotene 185 μg (180–190), thiamine 0.04 mg, riboflavin 0.08 mg, niacin 0.6 mg, and ascorbic acid 47 mg (20–126). The composition of okra leaves per 100 g edible portion is water 81.5 g (75.3–92.4), energy 235 kJ (56 kcal), protein 4.4 g (2.8–5.6), fat 0.6 g, carbohydrate 11.3 g, fiber 2.1 g, Ca 532 mg (258–635), P 70 mg, Fe 0.7 mg, β-carotene 385 μg, thiamine 0.25 mg, riboflavin 2.8 mg, niacin 0.2 mg, and ascorbic acid 59 mg. Compared to other fleshy fruit vegetables (tomato, eggplant), okra is particularly rich in Ca and ascorbic acid. Okra seed meal contains more than 20% of good-quality protein on a fat-free, dry weight basis, whereas most of the suitable amino acids in okra seed protein are present in amounts that are equal to or exceed the amounts in eggs and casein; the United Nations Food and Agriculture Organization references okra as a protein source. The seed protein is similar in amino acid composition to soybean protein. It contains 20% oil (similar in fatty acid composition to cottonseed oil). The seeds are rich in phenolic compounds, mainly composed of oligomeric catechins (2.5 mg/g of seeds) and flavonol derivatives (3.4 mg/g of seeds). The polyphenolic profile of the skin is composed principally of hydroxycinnamic and quercetin derivatives (0.2 and 0.3 mg/g of skins).[3]

Pharmacological Studies: Because of its high nutrient value, okra is considered a good source for food fortification strategies. Okra has also been used in the management of duodenal ulcers and diabetes. The glycosylated molecules found in okra mucilage have been related to the inhibition of adhesion of *Helicobacter pylori* to human gastric mucosa.[469] Such

molecules could also contribute to glucose entrapment and α-glucosidase inhibition that might be advantageous in the management of diabetes.[470] The fruit and the leaves have pronounced antioxidant properties. It has been observed that the distribution of phenolics in methanolic extracts of okra correlates with the distribution of antioxidant activity. Studies have also shown that roasting of okra seed flour at 160°C for up to 40 min caused an increase in antioxidant activity as determined by free radical scavenging using the DDPH assay.[471] A methanolic extract of okra seeds was shown to have antioxidant activity as evidenced by several criteria and to exert antihypoxic activity in two mouse models.[472] Oligomeric proanthocyanidins have been shown to be responsible for the α-amylase and α-glucosidase inhibitory activity of the seeds of unripe okra seeds. Thiolysis treatment of the proanthocyanidins using methyl thioglycolate produced thioether derivatives of (epi) gallocatechins and (epi)catechins as major products.[473]

Toxicity: Okra is a very common and popular vegetable with no known toxicity report. Both okra tofu and the protein-rich residue left after oil extraction have shown no acute toxicity and offer promise as food additive and animal feed ingredient. The seeds in the mature fruits yield oil that is similar to cottonseed oil and some varieties are said to contain gossypol or a gossypol-like compound. In some okra seed varieties, the oil contains small quantities of cyclopropenoid fatty acids with its strong physiological properties.

Formulation and Dosage Forms: Okra is usually available in food stores and health food outlets as fresh fruits or as frozen material. Sun-dried and horizontally or vertically sliced fruits are often sold in West African markets. Freeze-dried, microwave-dried, and controlled-temperature-backed fruits prepared with the aim of preserving the secondary metabolites have been packaged for the dietary supplement industry. The seeds have also been processed as nutraceuticals.

Commerce: Okra is grown throughout the world as an article of commerce. Countries in Asia and Africa are the major producers. The world production of okra as a fresh fruit vegetable is estimated at 6 million tons/year. Common okra makes up 90% of this amount and the West African species accounting for about 10% of the world production. In West and Central Africa, the common okra and its local variety are used in equal proportions.

Agriculture: Farmers usually use seeds harvested from their own local cultivar or rather heterogeneous landrace. The easiest way to keep the seed is to leave it in the pods. Seed weight varies from 30 to 80 g/1000 seeds. To soften the hard seed coat, the seed is often soaked in water or chemicals prior to sowing. The seed is usually dibbled directly in the field (1–3 seeds per hole). Optimum plant densities are in the range of 50,000–150,000 plants/ha. Emergence is within 1 week. When the plants are about 10 cm tall, they are thinned to one plant per hole. Germination and initial growth are improved greatly by cultural practices that lower soil temperature, for example, mulching, watering before the hottest part of the day, and sowing on ridge sides least exposed to direct sunlight. The robust West African okra should be grown at 20,000–50,000 plants/ha. Emergence is also within 1 week and the plants are then thinned to one plant per hole for optimum growth.

Commercial okra growers usually practice sole cropping, and prefer the early, homogeneous, introduced cultivars of common okra. In traditional agriculture, farmers grow their okra landraces in home gardens or in fields with other food crops. The landraces often consist of a mixture of *Abelmoschus caillei* and *Abelmoschus esculentus*, the former being predominant in humid climates, and the latter in drier climates. The uptake of minerals is rather high. Indicative figures for total nutrient uptake per ha of a crop with fruit yield of about 10 t/ha are 100 kg N, 10 kg P, 60 kg K, 80 kg Ca, and 40 kg Mg. Under humid tropical

conditions, a full-grown crop consumes about 8 mm of water per day. Some farmers practice ratoon cropping. A ratoon crop flowers soon after cutting, but usually results in poor-quality fruit with a high percentage of bent fruits. Organic cultivation of okra in North Central Nigeria yielded good fruits that are comparable in both composition and biomass with the plants grown with chemical fertilizer.

Palm Tree

Overview

The oil palm tree played a central role in the lives and culture of the rural communities in West and Central Africa during precolonial times. All parts of the plant are useful: the wood is used as frames for buildings, and the sap is fermented into *palm wine*; the oil from the mesocarp and the seeds are used for cooking and for making soaps, creams, and other cosmetics. The oil palm is a unique crop that produces two oils from its fruits—palm oil from the fruits' mesocarp and palm kernel oil from the seeds' endosperm (kernel). The most important product from the oil palm is perhaps the yellow- to red-colored oil known as palm oil from the mesocarp, which has a very balanced fatty acid composition—51% saturated fatty acids; 38% monounsaturated fatty acids; and 11% polyunsaturated fatty acids. The major saturated fatty acid is 38%–44% of palmitic acid (C16:0) and 4%–5% stearic acid (C18:0). Oleic acid (C18:1) represents 39%–44% and linoleic acid (C18:2) 10%–12% of the unsaturated fatty acids. It is also a rich source of carotenoids and polyphenols. Tocotrienols found in red palm oil are 40–60 times more potent than tocopherols as antioxidants. Red palm oil also has the highest content of tocotrienols of all edible oils, with rice bran oil as the only other edible oil that comes close, with just less than a third of the levels contained in red palm oil. Advocates of the consumption of red palm oil have suggested that the oil should be considered as a functional food to ameliorate the deleterious effects of oxidation and chronic inflammation. The protein hydroxylate from palm kernel cake yields antioxidant peptides with possible nutraceutical application.

Pharmacognostical Profile

Botanical Name: *Elaeis guineensis* Jacq.

Synonyms: *Elaeis nigrescens* A. Chev.; *Elaeis virescens* A. Chev.; *Palma oleosa* Mill.

Family: Arecaceae

Common Names: Oil palm, palm tree, king palm (*Elaeis guineensis* var. *idolatrica*) (E). Palmier à huile (F).

African Names: Bambara: m'te; Bini: udin; Hausa: kauku, kwakwa: Igbo: nkwu; Nupe: zukunnu: Swahili: mawese (palm oil); Tivi: irile; Urhobo: orien; Yoruba: ope, eyin

Description: The oil palm is a straight stemmed tree of up to 22 m high, with several prominent foliar scars, which increase with the age of the plant. The leaves are dark brown, about 7 m smaller than those of the *Raphia* species (raffia palm), and spiny at the base. The leaves gather at the top to form an umbrella-like canopy. Male and female inflorescences are borne at the axils of the leaves, with the male flowers being clusters of spikes, while the female flowers are in large stalkless heads. The fruits occur as ovoid drupes, with fibrous and oily mesocarp, bright red when ripe, appearing in clusters ranging from 3 to 10 kg. The seed, enclosed in a hard endocarp, contains an oily white albumen.



Habitat and Distribution: It occurs spontaneously in secondary forests, and as a derived crop in savanna and high forests. It is widely cultivated throughout the tropical forest regions. It is a major crop in Ghana, Nigeria, Togo, Ivory Coast, Uganda, Tanzania, and Kenya.

Culinary (Food) Use: All parts of the palm tree are useful either as food or as useful implement in cooking. Palm oil is used for cooking soups and frying foods, and as an ingredient in many African cuisines.

Ethnomedicinal Uses: *Elaeis guineensis* is one of the plants that is central to the lives of traditional societies in West Africa. All parts of the plant are useful: the wood, the sap, the oil from the mesocarp, and the seeds.

The fresh sap is used as a laxative, and the partially fermented palm wine is administered to nursing mothers to improve lactation. Ash from the palm fruit husk is used for the preparation of soap used to treat infections. A root decoction is used in Nigeria for headache; the pulverized roots are added to drinks for gonorrhea and menorrhagia, and as a cure for bronchitis. The leaf extract and the juice from young petioles are used as an application to fresh wounds. The fruit mesocarp oil and palm kernel oil are administered as poison antidote and used externally with several other herbs as a lotion for skin diseases. Palm kernel oil is applied to convulsant children to regulate their body temperature.

Constituents: The mesocarp yields a yellow- to red-colored oil known as palm oil, which has a very balanced fatty acid composition—51% saturated fatty acids; 38% monounsaturated fatty acids; and 11% polyunsaturated fatty acids. The major saturated fatty acid is 38%–44% of palmitic acid (C16:0) and 4%–5% stearic acid (C18:0). Oleic acid (C18:1) represents 39%–44% and linoleic acid (C18:2) 10%–12% of the unsaturated fatty acids. It has been observed that the fatty acid composition in palm oil is quite remarkable, with a structure of the fatty acids on the triglyceride backbone in which the majority (87%) of the unsaturated fatty acids are situated in the sn-2 position, whereas the saturated fatty acids are mostly in the sn-1 and sn-3 positions.[474] Normally, the sn-2 position monoacylglycerols are readily absorbed in the intestine. This unique structure in the palm oil triglyceride backbone therefore ensures that the unsaturated fatty acids in the sn-2 position are mostly absorbed from the intestine and that the saturated fatty acids in the sn-1 and sn-3 positions ensure stability and protection against oxidation. In addition, it contains among other things, glycerides of fatty acids with high molecular weights, including oleic acid (40%–50%) and myristic acid (1%–5%). The oil is also rich in carotenoids (including vitamin A and β-carotene) and sterols. Raw unprocessed palm oil normally contains 500–700 ppm

carotenoids, of which 35% is α-carotene and 56% is β-carotene. The refined red palm olein, however, contains 513 ppm carotene, of which 44% is α-carotene and 33.3% is β-carotene. Red palm oil also contains high levels of provitamin E (600–1000 ppm), with 78%–82% being tocotrienols and 18%–22% tocopherols.[475] It also elaborates the following phytonutrients: sterols (60–620 ppm), squalene (200–500 ppm), coenzyme Q10 (10–80 ppm), glycolipids (1000–3000 ppm), and triterpene alcohol (40–80 ppm). The kernel yields a pale yellow to colorless oil (palm kernel oil [PKO]) that comprises the following glycerides of fatty acid: lauric acid (50% of total fatty acids), myristic acid (15% of total fatty acids), oleic acid (15% of total fatty acids), and traces of linoleic acid and stearic acid.

Pharmacological Studies: Natural carotenes obtained from palm oil have been shown to suppress the promoting stage of two-stage carcinogenesis of mouse skin, and also inhibit the proliferation of human malignant tumor cells, such as neuroblastoma GOTO cells, stomach cancer HGC-27 cells, and pancreatic cancer PANC-1 cells.[476] The bright red nonsolid palm oil has strong antioxidant activity. Tocotrienols found in red palm oil are 40–60 times more potent than tocopherols as antioxidants. Red palm oil also has the highest content of tocotrienols of all edible oils, with rich bran oil as the only other edible oil that comes close, with just less than a third of the levels contained in red palm oil.[477]

The extract of the leaves has been evaluated for possible antioxidant activities by 2,2-diphenyl-β-picrylhydrazyl free radical-scavenging activity (DPPH), xanthine oxidase inhibition (XOI), nitric oxide-scavenging activity (NOS), and hydrogen peroxide-scavenging activity (HPSA) assays. It was found that the extract exhibited antioxidant activity with an IC_{50} value of 814 g/mL in the DPPH radical-scavenging method, 534.04 μg/mL in the NOS assay, 37.48 μg/mL in XOI, and 1052.02 μg/mL by the HPSA method based on the concentrations tested, respectively.[478] Palm kernel oil obtained from the seeds is used as lubricant and emollient for damaged skin and as suppository base. The soap prepared from the palm husk ash possesses antimicrobial properties.

Nine antioxidative peptide fractions have been identified from protein extracted from oil palm kernel that was hydrolyzed using pepsin–pancreatin (OPKH). Antioxidant capacities (ACs) of the purified peptides from OPKH were evaluated using ferric reducing antioxidant power (FRAP), β-carotene-linoleate bleaching (BCB) assay, and 2,2-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) radical-scavenging activity assay. The amino acid sequence of the antioxidative peptide was identified by liquid chromatography–electrospray ionization/multistage mass spectrometry (LC–ESI-Q-TOF–MS/MS) using *de novo* sequencing. Out of the nine fractions purified and collected, one of them, F6, demonstrated the highest AC. Three antioxidative peptides, Val–Val–Gly–Gly–Asp–Gly–Asp–Val (VVGGDGDV), Val–Pro–Val–Thr–Ser–Thr (VPVTST), and Leu–Thr–Thr–Leu–Asp–Ser–Glu (LTTLDSE) were identified in fraction F6. These peptides did not show any similarity with other antioxidant peptides listed in the BLAST database of NCBI.[479]

Pawpaw: Papaya

Overview

Pawpaw produces fruits that vary enormously in shape and size; most are oblong, globular, or round. The ripe fruit is yellow or bright orange in color. The pulp is thick and yellow-orange in color. The seeds are small dark-green or brown, enclosed in a

mucilaginous mass. The whole plant yields copious white latex when cut, which is composed of the proteolytic enzymes papain and chymopapain. It is used as a digestive aid and dietary source of vitamins and minerals. It has been used to produce juices, marmalades, jellies, smoothies, and other dietary products. It possesses anticancer and wound-healing properties. Chymopapain is employed in the treatment of herniated disks by chymonucleolysis.

Pharmacognostical Profile

Botanical Name: *Carica papaya* L.

Synonyms: *C. hermaphrodita* Bianco; *C. mamaya* Vellon.; *Vasconcellea peltata* (Hook. & Arn.) A. DC.

Family: Caricaceae

Common Names: Pawpaw, papaya

African Names: Arabic: anbah hindi, babaya, babog fruta bomba; Hausa: gwandu; Igbo: okworo-beke; Efik: Etighi-mbakara; Swahili: papaya; Yoruba: ibepe, sayinbo



Description: A small tree with weak soft-wooded stem and palm-like appearance. The stem is usually unbranched and hollow; the bark is gray and visibly marked by the numerous large orbicular leaf scars. The leaves are dark-green, very large, and crowded on the upper part of the tree, each borne in a long, hollow, and cylindrical petiole. They are suborbicular, 20–60 cm wide, usually palmately lobed, and each lobe pinnatilobulate, obtuse or acute. It is usually dioecious, male and female inflorescences being borne on different plants, although in rare occurrences some plants sometimes bear bisexual flowers. The male inflorescences are carried in the axils of the upper leaves, a long pendulous raceme carrying the numerous sessile male flowers on the branches. The male flowers are usually very fragrant. The female flowers are remarkably much larger than the male and more or less without stalks (sessile) and are borne on the main axils.

The plant produces fruits that vary enormously in shape and size; most are oblong, globular, or round, often five-angled and narrowed to the stigma tip, although flask-shaped fruits narrow at the base are not uncommon. The ripe fruit is yellow or bright orange in color. The pulp is thick and yellow-orange in color. The seeds are small dark-green or brown, enclosed in a mucilaginous mass. The whole plant yields copious white latex when cut.

Habitat and Distribution: Cultivated and grown widely in most parts of the continent. Native of tropical Africa.

Culinary (Food) Use: The fruits are consumed as food and in the preparation of salads, juices, and jellies. The leaves are used as meat tenderizers.

Ethnomedicinal Uses: Pawpaw is used in traditional medicine for a variety of purposes. The green fruit is applied on ringworm and is claimed to effect a cure if rubbed hard until the skin bleeds. The ripe fruit is edible and rich in vitamin A and has some vitamin C. A weak decoction of the leaves is taken for malaria, and the mixture with lemongrass and guava leaves in the treatment of hypertension. The three plants are also used with leaves of neem, *Azadirachta indica*, in steam therapy for malaria, in which the patients are covered with a thick blanket and made to bathe in and inhale the vapor from the cook pot.

The leaves and seeds are used for the treatment of amebiasis and as an anthelmintic. The fresh fruits are carminative and administered for digestive conditions, and as diuretic, stomachic, and antiseptic. The sap of the plant contains a ferment, which has the property of coagulating milk and of softening or digesting the fibrous tissues of flesh; hence, it is used to make meat tender, either by adding a piece of unripe fruit to the water when cooking, or by wrapping the meat in the leaves to roast or bake, or as a preliminary treatment for some hours before cooking. The seeds are used as oxytocic and externally as an antifungal agent.

Constituents: The principal constituents of papaya are the proteolytic enzymes found in the latex, which abounds in all parts of the plant, but is obtained mainly from the fruit, seed, and leaf. The two major enzymes in the mixture are papain and chymopapain, with papain occurring in less quantity but with twice the proteolytic activity of chymopapain. Commercially available "purified papain" usually consists of mixture of the two enzymes and small amounts of other enzymes. An alkaloid carpaine occurs in the seed and leaf, with traces in the unripe fruit. The air-dried seeds yield 660–760 mg/100 g of the aglycone of glucotropaeolin, benzylisothiocyanate (BITC). The fruit is rich in vitamins B and C, and traces of vitamin A, and has a high content of potassium and other minerals. The leaves and the roots yield the alkaloids carpaine, isocarpaine, and dihydrocarpaine I and II.[480] In the young leaves, the alkaloid content is about 0.28%.[481] The seeds also contain fixed oils, carbohydrates, glycosides, carpasemine, and benzene senevol.[482] The bark contains a pentalcohol, xylitol, and saponins.

Pharmacological Studies: The proteolytic activity of the enzymes has being exploited as an aid in digestive disorders and malabsorption syndrome. The crude enzyme preparation is used in wounds and surgical incisions to promote healing and prevent sloughing in infected wounds.[483] A related enzyme leucopaine, has been shown to aid the regenerative processes of the injured tissue of rabbits and in the treatment of purulent wounds in 303 patients under clinical conditions.[484] The papaya enzymes are used as topical debriding agent, sometimes in conjunction with urea, in wound healing to facilitate wound cleaning from necrotic tissues, and to arrest local inflammation and purulent exudation. They are also applied in eye and spinal disorders.

The fruit is edible and rich in vitamin A and has some vitamin C; it is used in a variety of ways as a food and as a meat tenderizer. Chymopapain has been employed, with remarkable success, as an intervertebral disk injection in the lumbar spine (chemonucleolysis). For this purpose, it is recommended that the drug should be administered under local anesthesia rather than under general anesthesia.[485] The leaves have been shown to possess antiplasmodial activity against both chloroquine-sensitive and chloroquine-resistant *P. falciparum*.[486]

Aqueous extract of *Carica papaya* (CP) leaves exhibited antitumor activity and immunomodulatory effects.[487] In human peripheral blood mononuclear cells (PBMC), the production of IL-2 and IL-4 was reduced following the addition of CP extract, whereas that of IL12p40, IL-12p70, IFN-γ, and TNF-α was enhanced without growth inhibition. In addition, cytotoxicity of activated PBMC against K562 was enhanced by the addition of CP extract. Moreover, microarray analyses showed that the expression of 23 immunomodulatory genes, classified by gene ontology analysis, was enhanced by the addition of CP extract. In this regard, CCL2, CCL7, CCL8, and SERPIN B2 were representative of these upregulated genes, and thus may serve as index markers of the immunomodulatory effects of CP extract. It is interesting to note that the identified active components of CP extract, which inhibited tumor cell growth and stimulated antitumor effects, have a molecular weight of less than 1000. It has been suggested that the CP leaf extract may potentially provide the means for the treatment and prevention of selected human diseases such as cancer and various allergic disorders, and may also serve as immunoadjuvant for vaccine therapy.[488]

The methanolic extract of the seeds showed male contraceptive activity in laboratory animals. Treatment at various dose regimens, daily for 52 weeks, did not show significant changes in body weight, organ weight, food and water intake, and preterminal deaths compared to those of control animals. Sperm count and viability in 50 mg/kg body weight treated animals and the weight of epididymis, seminal vesicle, and prostate of all the treated animals showed significant reduction compared to the control. Cauda epididymal spermatozoa of 50 mg/kg body weight treated animals were immotile. Azoospermia was observed at various doses in the treated animals. Serum clinical parameters, serum testosterone, and histopathology of vital organs were comparable to those of control animals. It was also reported that the histology of testis revealed adverse effects on the process of spermatogenesis, while the histology of epididymis, seminal vesicles, and ventral prostate showed no changes compared to the control.[489]

Clinical Applications: The proteolytic enzymes are listed in most pharmacopeia and are incorporated into proprietary products for digestive disorders. Papain has been given as enteric-coated tablets in a dose of 1.98 g with every meal to reverse a malabsorption syndrome that was incompletely controlled by a gluten-free diet and considered to be due to transient gluten intolerance.[490] The enzyme is dispensed as antitoxic agent for diphtheria and tetanus, and used externally for the healing of wound sores. A 4% w/v solution of the homogenized fruit pulp and 1% boric acid has been found very effective in the healing of tropical sores. Chymopapain is employed in the treatment of herniated disks by chymonucleolysis. Reviews on the use of chymopapain in the repair of disk disorders are available.[491,492]

The alkaloids have broad-spectrum antimicrobial activity. Carpaine inhibits the tuberculosis bacteria, *Mycobacterium tuberculosis*, but in high doses possesses a digitalis-like action that may cause cardiac paralysis and depression. In small doses (0.01–0.02 mg/day orally or 0.006–0.01 mg/day subcutaneously), carpaine hydrochloride was found useful in hypertension.[340] Tropaoline is bactericidal and has been indicated for intestinal and injury infections. Xylitol possesses antihemolytic activity and has been reported to lower bilirubin levels in rats intoxicated with parenteral administration of saponins.[493] A paste made from the leaves of pawpaw, mixed with opium and sodium chloride, applied for 3 days was found helpful in the relief of symptoms and easy extraction of guinea worm from the body.[494] The leaf extract is also effective against dengue fever.

Toxicity: Allergic reactions to papaya appear to be common.[495] Rhinitis, asthma, and other allergic reactions are sometimes experienced by health professionals handling papain-containing powders. A major adverse reaction associated with chymopapain is anaphylaxis, which can occur in up to 1% patients.[496] Papaya, in addition to glucosinolates, also contains low levels of cyanogenic glycosides (CNGs), an unusual occurrence because it was assumed that the two classes of metabolites were mutually exclusive. It is suggested that CNGs may be responsible for the antibiotic effects of the seeds and the laxative effect of the immature fruit. The accumulation of CNGs in the latex and leaves of papaya, although currently detected in edible parts at very low levels, may have potential human health implications.[497]

Pigeon Pea

Overview

Pigeon pea is a nitrogen-fixing legume cultivated in warm semiarid and subhumid tropical regions of the continent. It contains more than 20% protein, many essential amino acids, nonprotein amino acids, fats, carbohydrates, saponins, stilbenes, flavonoids, and isoflavones, as well as minerals, such as calcium, phosphorus, and iron. The leaves contain the phytoalexins, pinostrobin and cajaninstilbene acid, and the coumarin, cajanuslactone (7-hydroxy-5-*O*-methyl-8-(3-methyl-2-butylene)-4-phenyl-9,10-dihydro-benzopyran-2-one). Cajanus is a strong antioxidant and anti-inflammatory agent. An aqueous formulation called Cyclavit (Neimeth International Pharmaceuticals) is used for the management of sickle cell anemia in West Africa. It possesses antifungal, antidiabetic, and anticholesterolemic activities. In laboratory animals, the antidyslipidemic activity of pigeon pea was evaluated by a high-fat-diet (HFD) hamster model, in which the level of high-density lipoprotein-cholesterol (HDL-C), low-density lipoprotein-cholesterol (LDL-C), total cholesterol (TC), and total triglyceride (TG) were examined. It was found that pigeon pea administration promoted cholesterol converting to bile acid in HFD-induced hamsters, thereby exerting hypolipidemic activity.

Pharmacognostical Profile

Botanical Name: *Cajanus cajan* Millsp.

Synonyms: *Cyticus cajan* L.; *Cajanus indicus* Spreng.

Family: Leguminosae

Common Names: Pigeon pea, field-pea, pois d'Angol, Ambrebdade (Comores). Pois de pigeon (F)

African Names: Arabic: bisellat el-Haman; Hausa: waken-masar, waken-turawa; Igbo: fio-fio; Swahili: mbaazi; Yoruba: otili, otinli

Description: Annual or biennial shrub 2 m high with ribbed, silky pubescent stems. The stalks and leaves are covered with white down. It has three leaflets, oblong lanceolate, in short stalks. The flowers are brownish-yellow, borne on corymbiform racemes. The fruits occur as oblong linear pods (over 5 cm long), obliquely constricted between the seeds that vary from 3 to 4.[33]



Habitat and Distribution: Pigeon pea is pantropic and is cultivated in most parts of the continent. The plant prefers savannah vegetation and dry forest lands.

Ethnomedicinal Uses: The leaves are used as a weak decoction for the treatment of measles, catarrh, and hepatitis. An aqueous infusion of the seeds sometimes mixed with the leaves is dispensed for the management of sickle cell anemia.

Constituents: *Cajanus* contains amino acids, proteins, fats, carbohydrates, saponins, stilbenes, flavonoids, and isoflavones.[498] It also yields minerals, such as calcium, phosphorus, and iron. The leaves contain the phytoalexins, pinostrobin and cajaninstilbene acid, and the coumarin, cajanuslactone (7-hydroxy-5-*O*-methyl-8-(3-methyl-2-butylene)-4-phenyl-9,10-dihydro-benzopyran-2-one).[499] Urease has been isolated from pigeon pea. The enzyme is used in diagnostics to determine urea present in the blood serum.

Pharmacological Studies: The seed extract has been shown to possess hypoglycemic and antimicrobial activities.[500] Later studies on the hypoglycemic activity of the extract showed that the extract produced transient hypoglycemia at a dose of 300 mg/kg. Extracts of the seeds were effective in restoring the normal morphology of erythrocytes from blood samples of patients affected by sickle cell anemia.[501,502] The aqueous alcohol extract, as well as cajaminose, an amino sugar isolated from it, prevented the sodium metabisulfite-induced sickling of red blood cells.[503] Phenylalanine has been isolated as the main constituent of the antisickling fraction of the seed extract and has been suggested as being probably responsible for the hematological effect.[504]

Viclin, a holoprotein that occurs in seeds, exhibits an unusual stability to the denaturation by 8 M and 6 M guanidine-HCl.[505] The presence of urease in the plant may play some role in its use as an antisickling agent.

A *Cajanus* flavanone, pinostrobin, inhibits voltage-gated sodium channels of mammalian brain ($IC_{50} = 23\ \mu M$) based on the ability of this substance to suppress the depolarizing effects of the sodium channel selective activator veratridine in a synaptoneurosomal preparation from mouse brain. The resting membrane potential of synaptoneurosomes was

unaffected by pinostrobin. The pharmacological profile of pinostrobin therefore resembles that of depressant drugs that block sodium channels.[506] Cajanus has demonstrated antifungal, antioxidant, and hypercholesterolemia effects in laboratory experiments. Genistein and apigenin from the roots showed remarkable antioxidant properties using the DPPH-scavenging activity model.[507] The antidyslipidemic activity of pigeon pea was evaluated by the HFD hamster model, in which the level of high-density lipoprotein-cholesterol (HDL-C), low-density lipoprotein-cholesterol (LDL-C), total cholesterol (TC), and total triglyceride (TG) were examined. It was found that pigeon pea administration promoted cholesterol converting to bile acid in HFD-induced hamsters, thereby exerting hypolipidemic activity. It significantly increased hepatic carnitine palmitoyltransferase-1 (CPT-1), LDL receptor, and cholesterol 7α-hydroxylase (also known as cytochrome P450 7A1, CYP7A1) expression to attenuate dyslipidemia in HFD-fed hamsters, and markedly elevated antioxidant enzymes in the liver of HFD-induced hamsters, further alleviating lipid peroxidation. This activity was attributed to a possible role of the large quantity of unsaturated fatty acids (UFA; C18:2) and phytosterol (β-sitosterol, campesterol, and stigmasterol) present in pigeon pea.[508]

Red Pepper

Overview

Capsicum is well known for its spicy fruits that are used as a condiment for cooking throughout the world. It is a rubefacient, carminative, and antioxidant. The main constituents of the fruits are capsaicin, dihydrocapsaicin, nordihydrocapsaicin, and related alkaloids as well as vitamins A and C and the carotenoids, β-carotene, and β-cryptoxanthin.

Pharmacognostical Profile

Botanical Name: *Capsicum annuum* L.

Synonyms: *Capsicum cerasiforme* Lank.; *Capsicum chamaecerasus* Nees.; *Capsicum longum* DC. Over 30 synonyms and varieties are known to exist.

Related Species: *Capsicum annuum* var. *glabriusculum* (Dunal) Heiser & Pickersgill

Family: Solanaceae

Common Names: Red pepper (E). Piment doux. Piment des jardins. Gros piment. Poivron (F)

African Names: Arabic: filfil romi; Bambara: forotu, kilikili; Hausa: barkono, barkhannu; Igbo: totoshi; Swahili: pilipili-hoho; Yoruba: ata wewe

Description: *Capsicum annuum* L. is an annual or biennial suffrutescent plant that can reach over 1 m in height. The leaves are ovale lanceolate, 6 × 3.5 cm. The flowers are greenish-white borne on axillary bunches. It produces polymorphic berries 18 cm long, usually globular, ovoid, or oblong in shape, green colored and yellow to red when ripe.

Habitat and Distribution: The species is cultivated throughout tropical Africa; several hybrids and strains are known.

Culinary (Food) Use: Red peppers are used as condiments to impart a hot spicy taste to food. They are ingredients in the preparation of African pepper soup.

Ethnomedicinal Uses: The fruits are used as a carminative, tonic, spasmolytic, antiseptic, rubefacient, and stimulant. In traditional medicine, they are employed mainly as

a flavoring agent in compound formulations. A poultice prepared with the ground fruits, kaolin, and bark of *Newbouldia laevis* is used in postpartum medication as a general tonic. An ointment prepared with the fruit extract is used topically for skin infections.

Constituents: The fruit contains capsaicin, dihydrocapsaicin, nordihydrocapsaicin, and related alkaloids. Capsaicin content increases with maturation of the fruit. The color of the fruits is due to the presence of carotene, capsanthin, and capsorubin, as well as steroidal saponins. Vitamins A and C also occur in the plant. The common carotenoids with provitamin A activity, β-carotene and β-cryptoxanthin, occur in the plant.[509]

Pharmacological Studies: The alkaloid capsaicin has been studied extensively, and has been shown to possess antimicrobial, spasmolytic, vasodilation, rubefacient, counterirritant, and stimulatory activity on the digestive system. It has a somewhat ambiguous effect in the stomach mucosa. It has shown the ability to excite and later defunctionalize a subset of primary afferent neurons and has been extensively used as a probe to elucidate the function of these sensory neurons in a number of physiological processes. In the rat stomach, experimental data provided clear evidence that capsaicin-sensitive (CS) sensory nerves are involved in a local defense mechanism against gastric ulcers. Stimulation of CS sensory nerves with low intragastric concentrations of capsaicin protected the rat gastric mucosa against injury produced by different ulcerogenic agents. High local desensitizing concentrations of capsaicin or systemic neurotoxic doses of the agent markedly enhanced the susceptibility of the rat gastric mucosa to later noxious challenge.[510]

One of the steroidal saponins found in the fruits exhibited antibacterial activity.[511] The fruit extract has been employed in various formulations: gargle for laryngitis, improvement of peripheral circulation, alleviation of flatulence and colic, and externally as an ointment for lumbago, unbroken chilblains, muscle pains, and stiffness. Hot pepper has antioxidant activity, which is due to its phenolic content. Both ripe and unripe hot peppers prevented Fe^{2+}-induced lipid peroxidation in the rat brain. The unripe pepper had a significantly ($P < 0.05$) higher total phenol, Fe^{2+}-chelating ability and inhibitory effect on the basal and Fe^{2+}-induced lipid peroxidation in the brain tissues than the ripe pepper.[512]

Most pharmaceutical application of *Capsicum* is done with *Capsicum* oleoresin, a thick, dark reddish-brown liquid concentrate produced by the extraction of fruits with volatile solvents or by supercritical fluid extraction. The capsaicin content of *Capsicum* oleoresin is highly variable, and the oleoresin exhibit differences in its ability to mediate substance P release, the neuropeptide which causes vasodilation due to the release of nitric oxide from the endothelium. The quality of the oleoresin has to be tightly controlled for uniform pharmacological outcome since the liquid contains over 100 chemicals, alcohols, carbonyls, carboxylic acids, esters, pyrazine compounds, and terpenes in the volatile component of the resin.

Cayenne Pepper

Botanical Name: *Capsicum frutescens* L. (=variety: *Capsicum annuum* APG)

Synonym: *C. frutescens* var. *minimum*; *C. baccatum* L.; *C. fastigiatum* BI

Family: Solanaceae

Common Names: Fructus Capsici, African Capsicum, Japanese chilies, piment de cayenne, piment enrage (F), Pilipili (Francophone Africa), Cayenne pepper

Description: A perennial branchy shrub, ca. 1 m in height. It produces yellowish-white flowers. The fruits are smaller than those of *C. annuum*, oblong conical, obtuse, and binocular, rarely exceeding 4 cm. They are more pungent than those of *C. annuum,* with color ranging from red, yellowish red, to brownish red; they have a characteristic odor that can be modified by selective breeding.

Constituents: The plant contains up to 14% capsaicin, the pungent principle in the genus. It yields in varied concentrations the compounds reported above for *C. annuum.* The pungent properties of *Capsicum* can be distinguished from those of gingerol and paradol (found in Zingiberaceae) by the ability of the pungent substance in *Capsicum* to be resistant to destruction by solutions of caustic alkalis (1 in 50), but destroyed by potassium permanganate.

Pharmacological Studies: The biological activities are similar to those reported for *C. annuum.* The dietary hot short pepper showed antioxidant activity and prevented cyclophosphamide-induced oxidative stress in the brain. Although the flesh is a better protectant, the possible contributory role of the seeds cannot be ruled out.[513]

Rooibos

Overview

Rooibos tea is becoming the beverage of choice for healthy living enthusiasts because of its comparatively low tannin status and antioxidant property, and because it is caffeine-free. In addition to its use as an herbal tea, extracts prepared from rooibos are also used by the beverage, food, and nutraceutical markets, for their flavor and/or antioxidant properties. It contains polyphenols, caffeic acid, and a chalcone, aspalathin. The characteristic aroma, taste, and mouthfeel of fermented rooibos tea have been attributed to the presence of *Z*-2-(b-D-glucopyranosyloxy)-3-phenylpropenoic acid (PPAG). Pretreatment of rooibos with food-grade cellulase, ferulic acid esterase, and/or pectinase increased the total soluble solid yield from green and fermented rooibos when preparing an infusion, whereas ferulic acid esterase and β-glucanase/β-xylanase increased the total polyphenol yield.

Pharmacognostical Profile

Botanical Name: *Aspalathus linearis* (Burm. f.) R. Dahlgren

Synonyms: *Aspalathus tenuifolia* DC., Prodr.; *Aspalathus contaminatus* Druce; *Spartium contaminatum* L.; *Aspalathus corymbosa* C.A. Mey.; *Lebeckia linearis* (Burm.f.) DC.; *Psoralea linearis* Burm.f.

Family: Leguminosae

Common Names: Rooibos, Rotbush, aspalathus, *Herba Aspalathi*, bush tea, bushman, mountain tea, red bush, red bush tea, rooibos tea

African Names: Afrikaans: rooibos; South Africa: koopmanstee, naaldtee rooibostee

Description: *Aspalathus linearis* has been described as an erect to spreading, highly variable shrub or shrublet up to 2 m high. Its young branches are often reddish. The leaves are green and needle-like, 15–60 mm long and up to about 1 mm thick. They are without stalks and stipules and may be densely clustered. The yellow flowers, which appear in spring to early summer, are solitary or arranged in dense groups at the tips of branches. The fruit is a small lance-shaped pod usually containing one or two hard seeds.[1]

Habitat and Distribution: Rooibos is native to South Africa, where it appears to be restricted only in the Cedarberg area and around the villages of Clanwilliam and Citrusdal, which are situated to the north of Cape Town in South Africa. Apparently, rooibos needs a very specific climate and soil to grow and elaborate its characteristic compounds, as efforts to cultivate rooibos in other areas or countries with similar climates have not been very successful.

Culinary (Food) Use: Rooibos is consumed as a noncaffeine tea.

Ethnomedicinal Uses: *Aspalathus linearis* is a major South African medicinal plant and has been used in the Cape region of that country for centuries. Its main uses in South African traditional medicine include alleviating infantile colic, allergies, asthma, and dermatological problems. It has also been used for its anti-inflammatory and antiallergic properties.

Constituents: Rooibos is the only known source of the chalcone aspalathin. Other phytochemicals found include nothofagin, caffeic acid, chrysoeriol, isoquercitrin, orientin, isoorientin, luteolin, vitexin, isovitexin, rutin, flavonoids, quercetin, and other polyphenols. It has been shown that pretreatment of rooibos with food-grade cellulase, ferulic acid esterase, and/or pectinase increased the total soluble solid yield from green and fermented rooibos when preparing an infusion, whereas ferulic acid esterase and β-glucanase/β-xylanase increased the total polyphenol yield. It was also found that a combination of β-glucanase/β-xylanase and pectinase increased the yield of soluble solids from fermented rooibos in industrial evaluations by 33%. However, the total polyphenol and antioxidant content was reduced due to the extraction of "inactive" sugar moieties. It was noted that although the enzyme treatment reduced the aspalathin content of the extract, there was a concomitant increase in its flavone counterpart, isoorientin, which may be of significant pharmaceutical value for the treatment of both types of diabetes mellitus.[514]

Pharmacological Studies: Although reports of double-blind clinical studies with rooibos are scarce in scientific literature, animal studies suggest it has potent antioxidant, immune-modulating, and chemopreventive effects. Clinical outcome observations have shown that consumption of rooibos tea may relief fever, asthma, insomnia, colic in infants, and skin disorders. Rooibos extracts are used in ointments against eczema. In South Africa, it is very common to give rooibos tea to babies who suffer from stomach cramps (colics).

The presence of quercetin and lutein has been linked to the prevention of cardiovascular diseases, some cancers, and stroke and has been supported by *in vitro* and animal studies. A trial to test the effects of rooibos on various biological markers considered to be indicative of risk for cardiovascular disease and other degenerative diseases has shown that a high intake of rooibos tea resulted in significant reductions in lipid peroxidation, LDL cholesterol, and triglycerides, and an increase in HDL cholesterol levels compared with the control group. The investigators concluded that rooibos lowered risk factors associated with degenerative heart diseases.[515] Rutin has been associated with the maintenance of blood vessels walls. The low level of tannins in rooibos is believed to prevent problems with iron absorption associated with some tannin-rich herbal teas. Some trade journal publications have suggested that rooibos extracts from fermented rooibos leaves could reduce cancerous transformation of mouse cells irradiation with x-rays but extracts from unfermented green rooibos tea did not show this protective effect.

According to entries in the free encyclopedia on the Internet, Wikipedia, rooibos is purported to assist with nervous tension, allergies, and digestive problems. Rooibos tea has been shown to inhibit *in vitro* activity of xanthine oxidase, yet an *in vivo* study has not been conducted. Xanthine oxidase (XO) plays a role in the conversion of purine to uric acid in humans and reducing the activity of XO could limit uric acid production, which would aid in the treatment of gout.

Toxicity: Rooibos is generally considered as nontoxic but a recent report identified a possible case of hepatotoxicity due to rooibos consumption.[516] However, it has been suggested that it was possible that the tea may have been contaminated by another hepatotoxic compound and or that the person may have had a genetic predisposition to react negatively to any one of the other bioactive properties found in the tea.

Commerce: Rooibos is a major herbal tea from South Africa. A trade controversy surrounding the name "Rooibos" became a case study on the possible abuse of intellectual property rights to gain illegal monopoly. In 1994, Burke International obtained a patent from the U.S. Patent and Trademark Office for the use of the name "Rooibos," which gave the company a monopoly on the use of the name in America at a time when it was virtually unknown in America. When the plant later entered more widespread use, Burke demanded that companies either pay fees for use of the name or stop its use. In 2005, the American Herbal Products Association and a number of import companies succeeded in challenging the trademark through petitions and lawsuits, and after losing one of the cases, Burke surrendered the name to the public domain.[517] However, it is interesting that South Africa has a legal framework for the protection and restriction on commercial use of the name Rooibos in that country. They have drawn parallel inferences to similar legislation that already exists in Europe (for the protection of the names Champagne and Port, for example). This is despite Rooibos South Africa's decision to contest the Burke trademark on the grounds that "rooibos" is a generic term, rather than claiming it as a geographic indication.[518]

Agriculture: Attempts to grow *Aspalathus linearis* outside its natural home in South Africa have not been very successful. PROTA4U[4] has outlined the following methodology: the seeds must first be scarified and then planted in acid, sandy soils. The local rooibos tea management board supplies seeds that have been treated and germinate easily. They are planted in seedbeds in March to a depth of 5–10 cm and are ready for planting out by July. Plants are generally rainfall dependent and the plants prefer not to be too wet. No fertilizing is required and the plants grow quite well in nutrient-poor conditions. The seeds are planted in February and March and then the seedlings are transferred to plantations. It takes 12–18 months before the shrubs are ready to be harvested. The plants are harvested once each year, from December through April. They are harvested up to a period of 5 years and then pulled out and new plants are planted. The basic method of rooibos harvesting has remained largely the same as the process used centuries ago. An environmentally friendly way of harvesting tea that involves cutting only the young branches is used. Once they are cut, they are neatly bound and transported to the process yards. The older branches are left on the tree and the bushes get slightly taller every year. The tea cuttings are chopped very fine and then bruised to ensure that the important chemical reaction that develops the characteristic color and flavor of the tea can take place. After watering and airing, the tea is left to "sweat" in heaps and it at this point that the tea acquires its typical reddish brown color and develops its sweet flavor. After the sweating process has been completed, it is spread out in a large drying yard to dry in the sun. The rest of the process involves sorting and grading the tea according to length, color, and flavor. The finished Rooibos is finally weighed, bagged, and sold to companies that pack the product in either teabags or in loose leaf form under their own brand names. There remains however the issue of whether spontaneous sprouting or seeding is the better method of propagation.[519]

Scent Leaf

Overview

Many members of the genus *Ocimum* are consumed as vegetables and spices in Africa. All of them are used for the preparation of remedies in African traditional medicine. The most

important ones include *O. basilicum*, *O. gratissimum*, *O. canum*, and *O. suave*. All four species are used as febrifuge and some are used as food flavors. They all yield volatile oils, but the oils differ significantly in their chemical composition. Scent leaf has diuretic, antioxidant, anti-inflammatory, antidiabetic, and antianxiety properties. A proprietary formulation of *Ocimum gratissimum* and *Vernonia amygdalina* (IHP) is used in Nigeria for the treatment of diabetes. Individual characteristics are discussed under the pharmacognostical profile below.

Pharmacognostical Profile

Botanical Name: *Ocimum gratissimum* L.

Synonyms: *O. viride* Willd.; O. *guineense* Schum. et Thonn.

Family: Lamiaceae

Common Names: Fever plant, fever leaf, fever plant of Sierra Leone, tea bush

African Names: Ashanti: nunum, onunum; Bini: ihiri eziza, aramogho; Ewe: debeshui, beblosi; Hausa: dai doya ta gida; Igbo: nchu-anwu; Efik: ntion; Malinke: su-guen-fira; Mandingo: sise-jambo; Mende: kumoi, kumwi; Timme: e-b' onto, o-gbonto; Yoruba: efinrin

Description: An erect, small shrub with many branches, usually not more than 1 m high. The leaves are simple, lanceolate to oblong, up to 9 cm long and 4.5 cm broad, with cuneate or unequal-sided base and toothed margins. They are sparsely hairy on the undersurface and pitted with glands. The veins are slightly hairy. The herbs have an aromatic smell when crushed. The flowers are creamy white or yellowish, and appear in paniculate racemes of about 12 cm long. The calyx is small, two-lipped; the upper lip is broadly oval in shape and with a tiny short point. The lower lip is oblong and toothed and the petals combine to form a lipped tube. The fruits occur as small four-lobed capsules.[1]



Habitat and Distribution: Occurs in deciduous forests and savannah. Commonly found around village huts and gardens, cultivated for its medicinal uses and as a food flavor.

Culinary (Food) Use: Scent leaves are used as soup flavoring and the dried leaves are used as teas.

Ethnomedicinal Uses: The whole herb is used throughout West Africa as a febrifuge and as an ingredient of many malaria remedies. The crushed leaves are instilled into the eye as a treatment for conjunctivitis. The oil from the leaves is regarded as highly antiseptic and has been applied for the dressing of wounds, as mouth gargle, and to prevent

postpartum sepsis. The leaves are used in Nigeria as a stomachic and as a catarrh remedy,[1] as well as a general tonic and antidiarrheal. The oil is used in many parts of West Africa to prevent mosquito bites. The oil mixed with alcohol is applied as a lotion for skin infections and taken internally for bronchitis. An infusion of the leaves, the so-called "ocimum tea" or "bush tea," is dispensed as a remedy for fever and as a diaphoretic.

The leaves are boiled with those of *Spondias* and the bark of *Funtumia elastica* and applied as treatment for hemorrhoids. The leaves are also applied externally for rheumatic pains and lumbago.

Constituents: The leaves yield a very aromatic volatile oil that consists mainly of thymol (32%–65%) and eugenol. The plant also contains xanthones, terpenes, and lactones. The chemical composition of *Ocimum gratissimum* essential oil varies enormously according to their chemotypes: timol, eugenol, or geraniol.

Pharmacological Studies: Thymol isolated from the plant has been shown to be antiseptic, antitussive, and antispasmodic.[520] Some of the observed biological activity of the plant could be due to the presence of xanthones, which have been associated with monoamine oxidase inhibition activity,[521] the tetraoxygenated xanthones with anticonvulsant properties, and the secoiridoids, which possess stimulant and antispasmodic properties. A fraction of the crude extract has been shown to contract guinea pig ileum and rat colon, and raises rat mean arterial blood pressure.[522] The volatile oil exhibited antimicrobial, insect repellent, and anthelmintic activity.[523] Oral and topical formulations of the plant have been evaluated in Nigeria.[1]

Ocimum leaf extract is effective in the treatment of malaria[524] and CNS diseases.[525] Evaluation of the CNS activity was done using the open-field and rota-rod tests; sleeping time induced by sodium pentobarbital (PBS, 40 mg/kg, intraperitoneally, i.p.) and anticonvulsant activity against seizures induced by both pentylenetetrazole (PTZ, 85 mg/kg, s.c.) and maximal electroshock (MES, 50 mA, 0.11 s) were determined. Essential oils obtained in each season were effective in increasing the sleeping duration and a preparation obtained in spring was able to protect animals against tonic seizures induced by electroshock. In each season, eugenol and 1,8-cineole were the most abundant compounds, and in spring, the essential oil presented the greatest relative percentage of sesquiterpenes, suggesting that these compounds could explain the differences observed in the biological activity in essential oils obtained in different seasons of the year.[526]

Ocimum suave

Botanical Name: *Ocimum gratissimum* subsp. *gratissimum*

Synonyms: *Ocimum trichodon* Bak.; *Ocimum dalabaense* A. Chev.

Family: Lamiaceae

African Names: Kipare: mrumbash, muodo; Kimeru: induka, mnuka; Kirufiji: kifumbazi; manyinyiikwa; Kisambaa: msumbasha, mvumbash; Kiswahili (Kiluguru): kivumbashi; Kiarusha: olmanyinyikwa olemura; Kiluguru: msuameno; Kigogo: iwenya, mzenye, izenhye; Kinyiramba: inengafai, ijembaei, idumbasi; Kinyaturu: lumbasi; Kinyamwezi: ilumbasye; Kihehe: iwenye; Rwanda: umwenya

Description: It is a much-branched herb of about 1–4 m high, with ribbed stem and glabrous branchlets. The leaves are simple, oppositely arranged, 3–12 cm long, 1.6 cm wide with ovate to ovate-lanceolate or sometimes lanceolate blade, and bluntly serrated margin. The apex is acuminate and the base is cuneate. It has terminal inflorescence with simple or paniculate racemes. The flowers are hermaphrodite, borne in whorls, and irregularly shaped. The corolla is a whitish or greenish-yellow tube, ca. 5 mm long, with four-lobed

upper lip. The calyx is distinctly hairy, 5–7 mm long, with an oval upper lip, with the lower lip displaying four triangular teeth. The herb gives a pleasant aromatic odor when crushed.[1]

Habitat and Distribution: Like other members of the genus, *Ocimum suave* is widely distributed throughout the continent. It is primarily a savanna species, occurring in a wide range of soils at altitudes between 100 and 20,000 m in areas receiving between 500 and 1500 mm or more annual rainfall. The plant is the dominant species in most of eastern and southern Africa. It has been found to occur in Rwanda, Burundi, Ethiopia, Somali, Uganda, Kenya, Botswana, Angola, Namibia, South Africa, Tanzania, Malawi, Zambia, and Zimbabwe. It also occurs in the west coast and grows well in Sierra Leone, Guinea, Ivory Coast, Nigeria, and Cameroon, as well as in North Yemen and Comoro Island.

Ethnomedicinal Uses: The plant is used as a local application for the relief of nasal congestion; for this purpose, the fresh herb is crushed and sniffed. Extracts of the plant have been used for the treatment of coughs, abdominal pains, and ear and eye inflammation, and as gargle for mouth infections. The FAO monograph of the species reported that decoction of root pieces is administered twice a day for barrenness. The drug was also listed for the regulation of menstruation and for the treatment of prolapse of the rectum. The smoke from the burning plant is used as a mosquito repellant. The plant is also used as a charm against evil spirits.

Constituents: *O. suave* has a high content of volatile oil, which consists mainly of eugenol.

Pharmacological Studies: The plant has antimicrobial activity. Other uses are as described for *O. gratissimum.* Eugenol is used extensively in restorative dentistry as a temporary filling material for root canal. The leaf of *O. suave* is used to perfume chewing tobacco and snuff. Most of the pharmacological activities described under *Ocimum gratissimum* L. are applicable to *Ocimum suave* Willd (*Ocimum gratissimum* subsp. *gratissimum*).

Ocimum sanctum

Ocimum sanctum is a synonym of *Ocimum tenuiflorum* L. The plant occurs in parts of northern and eastern regions of the continent. The medicinal uses are indicated for preceding species.

An alcoholic extract and aqueous suspension of the leaves of *Ocimum sanctum* have been reported as possessing an immunomodulatory effect on antigenic challenge of *Salmonella typhosa* and sheep erythrocytes in albino rats.[527] It was found that there was definite stimulation of humoral immunologic response as represented by an increase in antibody titer in both the Widal and sheep erythrocyte agglutination tests as well as by cellular immunologic response represented by E-rosette formation and lymphocytosis.

Sesame Seed: Benniseed

Overview

Sesame seeds are obtained from the fruits of *Sesamum indicum*, an annual plant growing 50–100 cm (1.6–3.3 ft) tall, with opposite leaves 4–14 cm (1.6–5.5 in.) long with an entire margin; they are broad lanceolate, to 5 cm (2 in.) broad, at the base of the plant,

narrowing to just 1 cm (0.4 in.) broad on the flowering stem. It produces an edible vegetable oil derived from the seeds. It is used for cooking in many parts of the world, and it is often used as a flavor enhancer in Korean, Chinese, Japanese, Middle Eastern, and Southeast Asian cuisines. It has a distinctive nutty aroma and taste. The oil is popular in Asia and is also one of the earliest-known crop-based oils, but worldwide modern mass production is limited due to the inefficient harvesting and processing methods used to extract the oil. Sesame seeds are small. Their size, form, and colors vary with the thousands of varieties now known. The seed are rich in proteins, amino acids, vitamins, minerals, lignans, and polyphenols. Sesame oil contains the following fatty acids: linoleic acid (41% of total), oleic acid (39%), palmitic acid (8%), stearic acid (5%), and others in small amounts. The oil is unique in having approximately equal monounsaturated (oleic acid) and polyunsaturated (linoleic acid) fats, together totaling 80% of the fat content. Sesame and honey derived from it have shown antioxidative, antibacterial, and probiotic growth-stimulatory activities. Polyherbal formulations containing sesame, *Coleus forskohlii*, and *Salacia reticulata*, standardized for sesamin, forskolin, and mangiferin, respectively, showed *in vitro* inhibition of pancreatic lipase with differing degrees and dynamics.

Pharmacognostical Profile

Botanical Name: *Sesamum indicum* L.

Synonyms: *Sesamum alatum* Thoninig; *Sesamum capense* Burm.; *Sesamum sabulosum* A. Chev.; *Sesamum indicum* L.; *Sesamum orientale* L.

Family: Pedaliaceae

Common Names: Benniseed (West Africa), sesame, benue oil seed, sim-sim (East Africa), sesamier (F)

African Names: Arabic: simsim; Bambara: benefin, bene; Hausa: ridi; Peuhl: beme, poeuloel; Sotho: molekelele; Swahili: ufuta; Yoruba: yanmoti

Description: An annual herb attaining up to 2 m in height, with divided or palmilobate stem. The leaves are hairy and opposite. The tubular flowers are white or pink with purplish-red spots. It produces erect capsules that are 5 cm long and awl-shaped. The seeds are nonwinged, reticulate or smooth, and asymmetrical; flattened, ovoid, pointed at one end, about 3–4 mm, 2 mm broad, and 1 mm thick, buff-colored or whitish, finely punctate, with four delicate longitudinal ridges at the hedges of the flat faces.

Habitat and Distribution: Sesame is native to Africa but the cultivated variety originated from India. It is grown as a cash crop in subdesert savanna. It is drought resistant and is cultivated in Chad, Sudan, Cameroon, Nigeria, Upper Volta, Ivory Coast, Mali, Senegal, and Ghana. It is now naturalized in many Asian countries, where it is cultivated. Sesame varieties have adapted to many soil types. The high-yielding crops thrive best in well-drained, fertile soils of medium texture and neutral pH. The crop has low tolerance for soils with high salt and water-logged conditions. Commercial sesame crops require 90–120 frost-free days. Warm conditions above 23°C (73°F) favor growth and yield. While sesame crops can grow in poor soils, the best yields come from properly fertilized farms.

Culinary (Food) Use: Sesame oil is used mainly for cooking and as an ingredient for salad dressing.

Ethnomedicinal Uses: A decoction of the leaves is used as an aphrodisiac. The Sortho drink a decoction of the plant for malaria and are reported to chew the leaf instead of tobacco. The powdered leaf is applied to snake bite by the Swahili and as a remedy for

cough and for bronchitis. Decoction of the seeds is administered in severe cases of hemorrhoids and the regulation of the menstrual cycle. Benniseed is used as a nutritive diet during convalescence.

Constituents: The seed contains up to 60% fixed oil, 20% proteins, 4% mucilage, and about 1% sesamin, a lignan. It also contains lignans, sesamolin, pinoresinol, and lariciresinol.[528] The oil consists of glyceryl esters of palmitic, stearic, myristic, oleic, and linoleic acids.

Pharmacological Studies: Sesamin has been shown to have insecticidal activity and is synergistic to *Pyrethrum*.[529] The oil has a demulcent, emollient, diuretic, emmenagogue, lactagogue, and laxative effect.[1]

Allergy: Sesame seeds and sesame oil are a serious allergen to some people, including infants.

Shea Butter Tree

Overview

The African shea tree (*Vitellaria paradoxa*) is notable for the nuts that yield an off-white or ivory-colored edible fat called shea butter, a triglyceride derived mainly from stearic acid and oleic acid. It is used in Africa for cooking and in traditional medicine for the preparation of emollients, anti-inflammatory medicine, and a massage oil for body pains. It is also used in cosmetics as a moisturizer, salve, or lotion. In the food industry, shea butter blended with other oils has been used as a substitute for cocoa butter in chocolates and ice cream. The chemical study of the seeds has revealed that it contains mostly palmitic, stearic, oleic, and linoleic acids, as stearodioleins, oleodistearins and palmitostearin, trioleins, and possibly oleopalmitostearin. Shea butter is used for a variety of health purposes, especially for skin care. Shea butter melts at body temperature and it is claimed that it absorbs rapidly into the skin, acts as a skin "refatting" agent, and has good water-binding properties. It has been incorporated in many topical products and cosmetics for the reduction of wrinkles, blemish reduction, treatment of stretch marks and hemorrhoids, as an antihistamine, and as a vehicle for intradermal application of active pharmaceutical agents intended for the treatment of subcutaneous diseases.

Pharmacognostical Profile

Botanical Name: *Vitellaria paradoxa* C.F.Gaertn.

Synonyms: *Butyrospermum paradoxum* (Gaertn. F) Hepper; *B. parkii* (G. don) (Kotschy)

Family: Sapotaceae

Common Names: Shea butter tree

African Names: Ewe: yo, yokuti; Hausa: kadanya; Igbo: osisi ori, okwuma; Nupe: kochi; Twi: kra-nku, nku; Wolof: karate; Yoruba: emi, emi-egidi

Description: A large and treasured tree that grows up to 14 m high, *Vitellaria paradoxa* has dark gray bark, rough, fissured, and exudes white latex when cut. It is easily confused with *Lophira alata*. The leathery leaves (22.5×8.5 cm) are borne in clusters at the ends of the twigs. They are rounded at both ends, although the base is sometimes wedge-shaped. The young leaves are densely hairy but the older ones are sparsely hairy, becoming smooth with age. There are many lateral veins that spread out almost at right angles to

the margins. It produces fragrant flowers, which appear in clusters at the ends of leafless twigs. They are whitish in color and sepals are covered with pinkish hairs.

The fruits are yellow in color, ellipsoid, 5 cm long and 2.5 cm broad. They usually contain one oval-shaped seed, but at times 2–3 such seeds may be contained in a fruit. The seeds are about 3 cm long, with a hard, bony seed coat and a shield-shaped scar, which is nearly as long and as wide as the seed.



Habitat and Distribution: *Vitellaria paradoxa* is common in the savanna areas of the continent. It is a major crop in Sudan, Senegal, Ghana, Nigeria, Niger, and Chad.

Culinary (Food) Use: Shea butter is an edible fat used for cooking and frying.

Ethnomedicinal Uses: The fat (Shea butter) is used as an ointment for rheumatic pains and boils. A decoction from the bark is used to facilitate child delivery and ease labor pains. The leaf extract is dispensed for headaches and as an eye bath. The seed decoction is used as a stimulant and carminative.[1]

Constituents: The seeds contain an edible fat (Shea butter), derived mainly from stearic acid and oleic acid, which is used for a variety of purposes in Africa. The chemical study of the seeds has revealed that it contains mostly palmitic, stearic, oleic, and linoleic acids, as stearodioleins, oleodistearins and palmitostearin, trioleins, and possibly oleopalmitostearin.[530] Mital has studied the physicochemical properties of Shea butter and reported that it melts at 37.8°C and when heated above 38.5°C, it is transformed to a less stable form, which takes 4 days to revert to the stable form. The melting point could be raised by the addition of either beeswax or hard paraffin.[531,532]

Pharmacological Studies and Uses: Shea butter is used for a variety of health purposes, especially for skin care. It has been incorporated in many topic products and cosmetics for the reduction of wrinkles, blemish reduction, treatment of stretch marks and hemorrhoids, as an antihistamine, and as a vehicle for intradermal application of active pharmaceutical agents intended for the treatment of subcutaneous diseases. Some of its constituents have anti-inflammatory, emollient, and humectant properties, as well positive effects on sinusitis and relief of nasal congestion and muscular pains.

Commerce: The Shea tree grows naturally in West Africa and is a slow grower, taking up to 20 years to bear its first fruits. The total volume of the West Africa trade in Shea butter was about US$ 1 million in 2012. The value chain for this product indicates that

much of the processing and value addition is done in Europe and the United States. The market value for the refined product is quite good with the selling price as follows: 1 lb naturally refined = $6.95; bulk purchases of up to 1760 lbs = US$3484 (1.98 per lb). The products are graded from A to F depending on the quality as determined by laboratory analysis of the triglycerides and fatty acids fraction, microorganism load, vitamins A and E, melting point, and physical examination, including cleanliness and moisture content.

Sisal

Overview

Agave leaf sap is globally important as a fresh beverage, fermented or concentrated. It is used as a sweetener but during concentration, a brown color develops that intensifies during storage and affects the composition of the sap. It is also considered as a source of functional food ingredients, such as prebiotic fructans and as a potent anti-inflammatory and antiulcerative agent.

Pharmacognostical Profile

Botanical Name: *Agave sisalana* Perrine
Synonym: *Agave rigida* Mill.
Family: Asparagaceae
Common Name: Sisal
African Names: Arabic: sisal, bambara, tangeka; Hausa: axomyis; Swahili: katani, mkonge



Description: Sisal is a perennial plant with short stem, numerous leaves (in rosette) that are thick, fleshy, thorny, and that can reach 2 m in height and 15 cm in width. The inflorescence occurs in panicles at the apex of a hardy and long central stem of 3–8 m; greenish-yellow flowers that rarely develop into capsular fruits and into seed, but produce a lot of plantlets that ensure fast propagation.

Habitat and Distribution: The plant is widely distributed throughout East and Central Africa. It is, however, cultivated in most tropical parts of the continent, requiring much sunlight and preferring areas such as highlands with two rainy seasons. Sisal is a major crop in Tanzania, Uganda, Angola, Mozambique, and Kenya.

Culinary (Food) Use: The dried leaves are used as tea.

Ethnomedicinal Uses: Sisal is used primarily as a source of commercial fiber. In traditional medicine in East Africa, the sludge obtained from the sap is used in the preparation of a lotion for the treatment of local inflammatory conditions.

Constituents: The fibers contain about 78% polysaccharide, of which about 84% consists of cellulose and the remainder pentosan. The juice of the leaves contains hecogenin as the major component, and other steroidal sapogenin, such as sisalagenin, tigogenin, and neotigenin. Other constituents include mucilage, pectines, mannitol, and reducing sugars. *Agave* contains phenolic compounds, including flavonoids. The use of high-temperature and high pressure reactors (PARR) for phenolics extraction of *Agave* proved to be more efficient compared to the conventional solid–liquid extraction at room temperature. It has been observed that increase in both temperature and extraction time led to a corresponding increase in the amount of phenolic compounds extracted and suggested that, after process optimization, *Agave* could be used as an interesting source of polyphenols.

Pharmacological Studies: Extracts of the plant have been found to be devoid of antibacterial activity.[533] The inflorescence and leaf, as well as the juice, showed positive hemolysis test[534] probably due to the saponin content of the plant. The D-mannitol present in the *A. sisalana* biomass waste may add economic value to the natural sisal fiber production chain since the compound is widely used in the pharmaceutical industry and also used as a raw material for the production of several types of polymers.[535] Hecogenin found in *Agave* has been shown to possess anti-inflammatory, antioxidant, and gastroprotective activities.[536] *Agave sisalana* constituents showed antiparasitic action against gastrointestinal nematodes (GINs) in livestock and the extracts could therefore be employed in parasite management methods in the livestock sector.[537]

Sorghum: Guinea Corn

Overview

Sorghum is perhaps Africa's biggest contribution to the world's major food crops. Global estimates indicate that only rice, wheat, maize, and potatoes play a larger role. However, the functionality of sorghum constituents beyond the normal nutrient value dwarfs the other plants. Sorghum grain is a traditional staple food in most of tropical Africa. It is a global grain used for the preparation of alcoholic beverages, malted drinks, baked goods, and other food products. The plant contains amino acids, protein, carbohydrates, and vitamins. The secondary plant metabolites found in red sorghum grain include apigenin, quercimeritrin, kaempferol glucosides, apigenidin glucosides, apigeninidin, luteolinidin, and 7-*O*-methyl-luteolin-glucoside. The color of the sorghum is dependent on the flavonoid–anthocyanin content, the red/purple variety had the highest levels of 3-deoxyanthocyanidins (8–187 μg/g) and the lemon-yellow sorghum had the highest levels of flavones

(268–362 μg/g). Sorghum extract reversed the anemic condition in experimental animals and is used clinically in the management of anemia. A standardized extract from *S. bicolor* stem developed at Intercedd Laboratories, Nsukka, Nigeria, called Phytoerythropoetin-K (PEP-K) has also demonstrated consistent value in the treatment of anemia in chronic diseases. It is believed to improve the iron-binding capacity (transferring) and the percent saturation, as well as better incorporation of iron in developing red cells. A patented product by Nigeria's National Institute for Pharmaceutical Research and Development (NIPRD) called Niprisan, which contains *Sorghum bicolor* leaves in a mixture with other plants, has been shown to be effective in the management of sickle cell anemia with remarkable results. A related product (also based on sorghum) called Jobelyn (formerly called Jubi formula) has been shown to be effective in the management of sickle cell anemia and anti-inflammatory and immune-modulating properties.

Pharmacognostical Profile

Botanical Name: *Sorghum bicolor* (L.) Moench

Synonyms: *Sorghum vulgare* Pers.; *S. drummondii*; *S. guineense*; *S. roxburghii*; *S. nervosum*; *S. dochna*; *S. caffrorum*; *S. nigricans*; *S. caudatum*; *S. durra*; *S. cernuum*; *S. subglabrescens*. Many varieties and cross-breeds.

Family: Poaceae

Common Names: Guinea corn, chicken corn, great millet, sorghum, milo, sorgo, sudangrass

African Names: East Africa: mtama, shallu, feterita; Egypt: durra; South Africa: kafir corn; Sudan: durra, feterita; West Africa: great millet, guinea corn, feterita. Other indigeous names are usually for the various millet varieties, especially pearl millet, *Pennisetum glaucum*. The names do not denote taxonomic differentiation or group, but rather a functional or agronomic classification.

Description: Sorghum is a cane-like grass growing up to 6 m tall. Most are annuals; a few are perennials. Their stems are usually erect and may be dry or juicy. The juice may be either insipid or sweet. Most have a single stem, but some varieties tiller profusely, sometimes putting up more than a dozen stems. These extra stems may be produced early or late in the season. Plants that tiller after the harvest has occurred can be cut back, allowed to resprout, and grown without replanting (like sugarcane). The leaves are alternate, simple; leaf sheath 15–35 cm long, often with a waxy bloom, with a band of short white hairs at the base near the attachment, reddish in dye cultivars, auricled; ligule short, c. 2 mm long, ciliate on upper free edge; the blade lanceolate to linear-lanceolate, 30–135 cm × 1.5–13 cm, initially erect, later curving, margins flat or wavy. The inflorescence occurs as a terminal panicle up to 60 cm long; the rachis are short or long, with primary, secondary, and sometimes tertiary branches, with spikelets in pairs and in groups of three at the ends of branches. The fruit—a caryopsis (grain), is usually partially covered by glumes, 4–8 mm in diameter, rounded and bluntly pointed. Soil permitting, the plant produces a deep tap root; some have a large number of multibranched lateral roots.

Habitat and Distribution: Sorghum is of African origin and is cultivated throughout the tropical parts of the continent. It is primarily a plant of hot, semiarid tropical environments but quite adaptable to very harsh ecological systems. It is particularly adapted to drought due to a number of morphological and physiological characteristics, including an extensive root system, waxy bloom on leaves that reduces water loss, and the ability to stop growth in periods of drought and resume it when the stress is relieved. A rainfall of

500–800 mm evenly distributed over the cropping season is normally adequate for cultivars maturing in 3–4 months. Sorghum tolerates waterlogging and can also be grown in areas of high rainfall. It tolerates a wide range of temperatures and is also grown widely in temperate regions and at altitudes up to 2300 m in the tropics. The optimum temperature is 25–31°C, but temperatures as low as 21°C will not dramatically affect growth and yield. Sterility can occur when night temperatures fall below 12–15°C during the flowering period.



Ethnomedicinal Uses: Sorghum grain is a traditional staple food in most of tropical Africa. It is a global grain used for the preparation of alcoholic beverages, malted drinks, and bakery, and for food purposes as is maize or wheat. In traditional medicine, it has various applications but usually in combination with other plants. The seed extracts are drunk to treat hepatitis, and decoctions of twigs with lemon against jaundice; leaves and panicles are included in plant mixtures for decoctions against anemia. One of the most remarkable uses of sorghum is in the preparation of an effective hemoglobin-regenerating tonic with the stalk, especially the red variety. For this purpose, the ground plant material is macerated with water–alcohol mixture with "potash" for 2 days, boiled for few hours with open pot, and left overnight before use. The tonic is administered for 2 weeks with observable effect on general health. The red pigment is used for the treatment of various microbial and fungal infections. In Nigeria, the red sorghum dyes were traditionally used by the Bunu, Aworo, Igbira, and Okpella people for a fabric called "abata," used as a funeral hanging, decorated with patterns made by thick threads added to the weft of the fabric. The fabrics in which the dominant colors were derived from sorghum were known as "ifala." Sorghum is also used to provide the violet colors decorating the masks worn during certain dances by Yoruba people in southern Benin and in south-western Nigeria. In Côte d'Ivoire, sorghum and other tannin-rich dyes are used in combination with mud to create the patterns of the painted cloths produced in the Korhogo region. The dye was formerly exported to Morocco where it was used in the leather industry.[1]

Constituents: According to the U.S. Department of Agriculture, the composition of sorghum grain per 100 g edible portion is water 9.2 g, energy 1418 kJ (339 kcal), protein 11.3 g, fat 3.3 g, carbohydrate 74.6 g, Ca 28 mg, P 287 mg, Fe 4.4 mg, thiamine 0.24 mg, riboflavin 0.14 mg, niacin 2.9 mg, and ascorbic acid 0 mg. The essential amino acid composition per 100 g edible portion is tryptophan 124 mg, lysine 229 mg, methionine 169 mg, phenylalanine 546 mg, threonine 346 mg, valine 561 mg, leucine 1491 mg, and isoleucine 433 mg. The principal fatty acids are per 100 g edible portion: linoleic acid 1305 mg, oleic acid 964 mg, and palmitic acid 407 mg. Sorghum grain is first limiting in lysine, then in methionine and threonine. Much of the protein in sorghum is prolamine (39%–73%), which is poorly digestible, making the maximum available protein in sorghum grain to be less than 10%. Apigenin, quercimeritrin, kaempferol glucosides, apigenidin glucosides, apigeninidin, luteolinidin, and 7-*O*-methyl-luteolin-glucoside have been isolated from red sorghum grain. The yields of some of the pigments are anthocyanidin apigeninidin (17%) and the flavonoids luteolin (9%) and apigenin (4%). The color of the sorghum appears to be dependent on their flavonoid–anthocyanin content, the red/purple variety had the highest levels of 3-deoxyanthocyanidins (8–187 μg/g) and the lemon-yellow sorghum had the highest levels of flavones (268–362 μg/g).[538]

Changes of the phytochemical profiles, antioxidant, α-glucosidase, and α-amylase inhibitory activities of sorghum grain during the processes of sorghum tea production have been observed.[539] Significant ($P < 0.05$) changes of total phenolics (TPC), total flavonoids (TFC), and procyanidins (PAC) contents were found in sorghum grains during the soaking, steaming, and roasting processing. Significant ($P < 0.05$) increases of ferulic (free) and *p*-coumaric acid (bound) were present in sorghum upon steam processing. Roast processing (150°C, 1 h) caused significant ($P < 0.05$) increases in phenolic acids, TPC, TFC, and PAC compared with the soaking and steaming stages. Accompanied with the changes of phytochemicals of sorghum grain, there were complex changes of biological activities during the successive processes. Our study also showed that there were positive linear correlations among TPC, TFC, PAC, and bioactivities of sorghum grain; however, PAC has the strongest correlation (0.979, 0.968, and 0.912, respectively, $P < 0.0001$) with DPPH radical-scavenging activity, α-glucosidase, and α-amylase inhibitory activities.

Pharmacological Studies: Sorghum is valued as a highly nutritious plant. Much published literature exists on the food value of this crop and therefore the emphasis here is on its possible medicinal uses. The use of the red pigment in the treatment of anemia has been confirmed in tests with rats. Sorghum stem extract was administered to 21-day-old weaning rats that were maintained on iron-sufficient or iron-deficient diets for 6 weeks before the administration of the aqueous extract of *Sorghum bicolor* stem bark at various doses for 7 days. The extract produced significant increase in hemoglobin, packed cell volume, and red blood cells in iron-sufficient and iron-deficient groups ($P < 0.05$). There was also significant increase ($P < 0.05$) in the catalase activity of the rat liver and kidney without any significant change ($P > 0.05$) in the serum catalase activity. The results showed that the extract reversed the anemic condition in the iron-deficient group and thus was indicative of the possible role of sorghum in the management of anemia.[540] A standardized extract from *S. bicolor* stem developed at Intercedd Laboratories, Nsukka, Nigeria, called Phytoerythropoetin-K (PEP-K) has also demonstrated consistent value in the treatment of anemia in chronic diseases. It is believed to improve the iron-binding capacity (transferring) and the percent saturation, as well as better incorporation of iron in developing red cells.[541]

A patented product by Nigeria's National Institute for Pharmaceutical Research and Development (NIPRD) called Niprisan, which contains *Sorghum bicolor* leaves in a mixture

with other plants, has been shown to be effective in the management of sickle cell anemia with remarkable results.[542] The patent described a phytochemical composition for treating sickle cell disease, composed of a cold water extraction product of a mixture containing *Piper guineenses* seeds, *Pterocarpus osum* stem, *Eugenia caryophyllum* fruit, *Sorghum bicolor* leaves, and potash. Also described are mixtures of phytomaterials used for preparing the extraction product, methods for making the extraction product, and methods for using the extraction product.

A related product marketed also in Nigeria, Jobelyn (formerly called Jubi Formula), has been shown to be effective in the management of sickle cell anemia. An *in vitro* study has been reported that examined the anti-inflammatory and immune-modulating properties of Jobelyn.[543] Freshly isolated primary human polymorphonuclear (PMN) and mononuclear cell subsets were used to test selected cellular functions in the absence versus presence of aqueous and ethanol extracts of *Sorghum bicolor* leaf sheaths (SBLS). Both aqueous and nonaqueous compounds contributed to reduced reactive oxygen species formation by inflammatory PMN cells, and reduced the migration of these cells in response to the inflammatory chemoattractant leukotriene B4. Distinct effects were seen on lymphocyte and monocyte subsets in cultures of peripheral blood mononuclear cells. The aqueous extract of SBLS triggered robust upregulation of the CD69 activation marker on CD3– CD56 + natural killer (NK) cells, whereas the ethanol extract of SBLS triggered similar upregulation of CD69 on CD3 + CD56 + NKT cells, CD3 + T lymphocytes, and monocytes. This was accompanied by manyfold increases in the chemokines RANTES/CCL5, Mip-1a/ CCL3, and MIP-1b/CCL4.[1]

(African) Star Apple

Overview

The African star apple (*Chrysophyllum albidum*) is the source of an occasional fruit that has a very limited seasonal use. It is cherished in West Africa despite its somewhat acrid taste due to a high concentration of ascorbic acid and other fruit acids. The fruit pulp is taken by pregnant women to prevent nausea. It has antioxidant properties.

Pharmacognostical Profile

Botanical Name: *Chrysophyllum albidum* A. DC.

Synonym: *Gambeya albida* (G.Don) Aubrev. & Pellegr.; *Planchonella albida* (G.Don) Baehni

Family: Sapotaceae

Common Name: White star apple

African Names: Ashanti: adesawa, adesaa; Bini: otien; Ewe: adansawa; Igbo: udara, udala; Twi: adios, asamfona-fufu; Yoruba: osan

Description: A tree of up to 30 m high and about 2.5 m in girth, with small buttresses at the base. The bole is long and often straight, occasionally branched low down. The bark is grayish-brown, with criss-cross depressions, a pale brown slash, and exudes copious, gummy white latex. The leaves are oblanceolate, acuminate at the apex and wedge-shaped at the base, about 30 cm long and 8 cm wide. The lower surface is densely covered with silvery-white or faintly yellowish silky hairs. It has a channeled midrib, with 10–15 pairs of lateral nerves; venation on the lower surface is not very distinct. The flowers are borne in

clusters in the leaf axils, shortly stalked, small and yellow; the sepals are about 2.5 mm long and covered with minute yellowish hairs. The fruits occur in January–February, edible, glabrous when mature, and ovoid to subglobose, pointed at the apex, up to 6 cm long, and pale orange when ripe. A cross section of the fruit, like that of *C. africanum*, reveals seeds arranged as a star. The seeds are 2.5 × 1 cm, with one sharp edge and the other blunt.[13]



Habitat and Distribution: Often cultivated, the wild species occur in closed forests, in the lowland rainforest regions. It is distributed from Gambia, Sudan, and Uganda to parts of South Africa.

Culinary (Food) Use: The fruits are edible.

Ethnomedicinal Uses: The bark is used in southern Nigeria as a remedy for malaria, sleeping sickness, and yellow fever. The Igbo regard the plant as a symbolic tree for the creative spirits and it is featured in healing rituals for female infertility. The leaves are used as emollients and for the treatment of skin eruptions. The leaf decoction is administered for diarrhea and for stomachache. The fruit pulp is taken by pregnant women to prevent nausea.

Constituents: The leaves and stems have been shown to contain β-amyrin acetate,[544] gentisic acid, and alkaloids.[545,546] The isoprene content of the latex has been characterized and was found to consist of polyisoprene, 1–4.[547] The fruits are rich in ascorbic acid.

Pharmacological Studies: The methanol extract of the seeds and roots exhibited antihistamine activity and potentiated the effects of antihistamine agents. The extracts also produced hypotension with simultaneous depression in respiration when administered to cats.[548] At a concentration of 100 ppm, the methanol extract of the seeds was found to possess strong molluscicidal activity against schistosomiasis-transmitting snails.[15]

Tamarind

Overview

Tamarind (*Tamarindus indica*, family Fabaceae) is a leguminous tree indigenous to tropical Africa, but has long been naturalized in Indonesia, India, Malaysia, the Philippines, and

the Pacific Islands. It produces edible, pod-like fruit, which is used extensively in cuisines around the world. The fruit flesh is highly acidic and consists of tartaric, citric, malic, and acetic acids. The fresh ripe tamarind is rich in reducing sugars (ca. 30%–41%). Interestingly, the unripe tamarind contains little sugar or acid, but may have vitamin C. The volatile oil is made of cinnamaldehyde, ethyl cinnamate, gerniol, limonene, α-terpineol, piperitone, alkylthiazoles, pyrazines, methylsalicylate, and safrole. All parts of the plant contain phenolics, including catechin, epicatechin, quercetin, and isorhamnetin. It is not surprising that tamarind has strong antioxidant properties because of the high concentration of phenolics in the leaves, fruits, seeds, veins, and skins. It is also antidiabetic, anti-inflammatory, and antihypercholesterolemic.

Pharmacognostical Profile

Botanical Name: *Tamarindus indica* L.

Synonyms: *Tamarindus occidentalis* Gaertin; *Tamarindus officinalis* Hook.

Family: Fabaceae

Common Names: Tamarind tree (E), Tamarinier, Tamarin (F)

African Names: Bambara: tombi, ntomi, tumi; Hausa: tsamyia, tsamia; Masai: ol massamburai; Nyamwezei: mshishi; Peuhl: dam, dabe, dami, djamini; Shona: musika; Swahili: ukwaju, mkwayo; Igbo: icheku; Yoruba: ajagbon

Description: The genus *Tamarindus* is a monotypic taxon, having only a single species. *Tamarindus indica* is a medium-sized tree, with a short bole, striped shaky dark brown bark, and a dense crown. The leaves are peripinnate with 7–12 pairs of opposite leaflets, unequally rounded at the base. The flowers occur in small terminal racemes, yellowish with red or purple stripes, with three petals and four sepals. It produces thick pods, about 10–20 cm long, with edible fibrous pulp with 5–6 seeds. The fruit has a faint, characteristic odor and the taste is acrid and sweet.

Habitat and Distribution: Tamarind occurs wild in the tropics and is widespread throughout the continent. It is probably native to Africa, as well as India. It is cultivated for its fruits and as shade and avenue trees. It is widely distributed, and is found in Ghana, Nigeria, Chad, Ethiopia, Angola, Kenya, and Tanzania.

Culinary (Food) Use: The ripe fruit pulp is edible and used to prepare a refreshing drink and is eaten as an occasional snack. It is also fermented into wine. The hard green pulp of a young fruit is used as a component of savory dishes, as a pickling agent, or in Ghana it used to make certain poisonous yams safe for human consumption.

Ethnomedicinal Uses: In northern Nigeria, tamarind roots are used as an ingredient in the preparation of medication for leprosy treatment. The leaves have been administered for fevers as a laxative. In many parts of West Africa, a decoction of the roots is the principal ingredient in remedy for cardiac diseases. The bark infusion is drunk by women after childbirth as a general tonic. The fruit pulp is processed in various ways and added to certain meals as a form of mild laxative. In northern Ghana, the Sokoto province of Nigeria, Chad, and southern Sudan, the evaporated pulp is often added to boiled cereal pap for the treatment of constipation. The leaves are used as a cicatrizer in wound dressing.

Constituents: The fruit flesh is highly acidic, and yields up to 15% tartaric acid. It also contains citric, malic, and acetic acids. The fresh ripe tamarind is rich in reducing sugars (ca. 30%–41%). The unripe tamarind contains little sugar or acid, but may have some

vitamin C. The plant also contains volatile oil, consisting of cinnamaldehyde, ethyl cinnamate, gerniol, limonene, α-terpineol, piperitone, alkylthiazoles, pyrazines, methylsalicylate, and safrole.[549] All parts of the plant contain phenolics, including catechin, epicatechin, quercetin, and isorhamnetin.

Pharmacological Studies: The fruit pulp has laxative properties and is highly nutritive. It is dispensed in China to treat nausea in pregnancy. The fruit pulp extract reduced the fluoride concentration in blood and bone and enhanced urinary excretion in animal studies, which is indicative of the ameliorative potential of fruits of tamarind in fluoride toxicity.[550] The pulp fruit extract (5%) given to hypercholesterolemic hamsters decreased the levels of serum total cholesterol (50%), non-HDL cholesterol (73%), and triglyceride (60%), and to an increase of high-density lipoprotein (HDL) cholesterol levels (61%). *In vitro*, the extract presented radical-scavenging ability, as assessed by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and superoxide radicals assays, and led to decreased lipid peroxidation in serum, as assessed by the thiobarbituric acid reactive substances (TBARS) assay.[551] It has antihyperglycemic properties and has been used for the treatment of diabetes.

Tamarind has strong antioxidant properties attributed to the high concentration of phenolics in the leaves, fruits, seeds, veins, and skins. The effects of solvents, of varying polarities, on the extraction of antioxidant phenolics from the leaves, seeds, veins, and skins of *Tamarindus indica* have been studied. The efficiencies of the solvents for extraction of the antioxidant phenolics were found to be in the order: methanol > ethyl acetate > hexane. Methanol leaf extract had the highest phenolic content and was the most potent scavenger of DPPH and superoxide radicals. Methanol vein extract had the highest ferric-reducing activity whereas methanol seed extract was the most potent ABTS radical scavenger. A positive correlation existed between phenolic content and antioxidant activities of the plant parts.[552] Four major antioxidants are known to occur in the plant: 2-hydroxy-3,4-dihydroxyacetophenone, methyl 3,4-dihydroxybenzoate, 3,4-dihydroxyphenylacetate, and epicatechin, as well as other minor phenolic compounds.

The most widely used tamarind is the seed extract—tamarind seed extract (TSE)—which has been shown to exhibit strong antioxidant-scavenging activity against hydroxyl radicals and superoxide anions produced by the ABTS/H_2O_2/$FeCl_3$ (Feton reaction) and hypoxanthine–xanthine oxidase (neotetrazolium) systems, respectively. It has also displayed scavenging activity against peroxyl radicals generated by ABTS/H_2O_2/peroxidase and ABTS/H_2O_2/myoglobin systems.[553] It inhibited the *in vitro* and *in vivo* production of both nitrite and NO. The anti-snake venom property of TSE has been evaluated. TSE completely inhibited the PLA2, protease, hyaluronidase, L-amino acid oxidase, and 50-nucleotidase enzyme activities of *Vipera russellii* venom dose-dependently. It completely neutralized the venom-induced edema, hemorrhage, and myotoxicity, including lethality. The venom-induced lethality ($2LD_{50}$ dose) was antagonized dose-dependently *in vivo*.[554] The seed coat has antioxidative activity, as well as antiacne and antidiabetic activity. It is also used as a tanning material.

Commerce and Agriculture: It is noteworthy that although tamarind is indigenous to Africa, the plant is not cultivated to any significant extent in the continent. Asian countries and the United States are the major commercial growers of the crop. Seeds are hard and before germination are scarified or briefly boiled. They can retain the germination capability after several months if kept dry. There is good market for the whole fruits, dried pulp, and processed products.

Tigernut

Overview

Tigernut is not a real "nut" but perennial tuber or rhizome rich in myristic acid, oleic acid, and linoleic acid. It has been reported to reduce the risk of colon cancer with positive effect on cholesterol level due to the high content of vitamin E. The seed contains about 36% oil; it is considered as a good source of seed oil. The fatty acid composition of the oil is mainly oleic, linoleic, and palmitic acids. Tigernut is prone to aflatoxin contamination and extra care must be exercised during processing in order to harness the full nutritional benefit of the plant in a safe manner. The oil from *C. esculentus* has been successfully used as a source of feedstock for the synthesis of a relatively cheap and nontoxic fatty hydroxamic acid (FHA), which has remarkable antioxidant and free-radical-scavenging activity.

Pharmacognostical Profile

Botanical Name: *Cyperus esculentus* L.

Synonyms: *Cyperus* spp. (34 synonyms, subspecies, and varieties); *Chlorocyperu saureus* (K.Richt.) Palla ex Kneuck.; *Chlorocyperus phymatodes* (Muhl.) Palla; *Pterocyperu sesculentus* (L.) Opiz; *Pycreus esculentus* (L.) Hayek

Related Species: *Cyperus rotundus* L.

Family: Cyperaceae

Common Names: Tigernut, yellow nutsedge, Chufa flatsedge, earth-almond, grass nut, rushnut, souchet sultan

African Names: Igbo (Nigeria): aki-awusa; Hausa (Nigeria): ayah, haya; Afrikaans (Namibia): geeluintjie, hoenderuitjie, uintjie; Afrikaans (South Africa): geeluitjie, hoenderuintjie, patrysuitjie; Damara/Nama (Namibia): !han; Khukh (Namibia): !hanni; Otjiherero (Namibia): okatjako; Shona (southern Africa): chufa; Shona (Zimbabwe): pfende; Mozambique: chimbwe-chimbwe; Zulu (South Africa): indawo, insikane; Dioula: tchoro toro; Bambara: nton togon; Malinke: toki

Description: Tigernut is an annual or perennial herb, cespitose or not, rhizomatous or not, stoloniferous or not. The roots are fibrous and principally adventitious. The stems (culms) are usually trigonous, occasionally serrated, rarely compressed, usually solid, rarely hollow or septate. The leaves are basal and/or cauline, alternate, usually three-ranked, rarely two-ranked or multiranked, the bases forming cylindrical sheaths enclosing the stem, margins usually fused; the junction of sheaths and blades often with adaxial flaps of tissue or fringes of hair (ligules); the blades frequently absent from some basal leaves, rarely from cauline leaves, when present divergent or ascending, flat, folded, plicate, rolled, or terete, linear, venation parallel. Primary inflorescences (spikelets) a shortened axis; glumaceous bracts (scales) 1–many, spirally arranged, sometimes two-ranked, usually appressed or ascending; the scales usually all fertile, each subtending a single flower, sometimes proximal and/or distal scales empty; lateral spikes often with basal, usually empty, usually two-keeled scale (prophyll); occasionally prophyll subtending and enclosing rachilla, bearing one pistillate, sometimes up to three staminate flowers and empty scales. Secondary inflorescence panicles, often modified to corymbs, pseudoumbel, cyme (anthela), raceme, spike, or capitulum (head), rarely single spike, usually subtended by foliaceous or, less frequently, glumaceous bracts; secondary inflorescences sometimes simulating spikelets. The flowers are hypogynous, bisexual in

most genera; perianth absent or with (1–) 3–6(–30) bristles and/or scales, usually falling off with fruit; stamens usually (1–) 3, rarely more, usually distinct; anthers basifixed; pistils 1, 2–3(–4)-carpellate, fused, locule 1; style undivided or branches 2–3(–4); stigma sometimes papillate. The fruit achenes are usually trigonous or biconvex; pericarps thin (except in *Scleria*).[1]



Habitat and Distribution: Tigernut is a perennial tuber or nut found in the wild and cultivated in drier parts of the continent. It has been cultivated since the fourth millennium BC in Egypt and for several centuries in other parts of North Africa and southern Europe. The plant prefers light (sandy), medium (loamy), and heavy (clay) soils and can grow in heavy clay soil. It requires moist or wet soil and prefers acidic, neutral, and basic (alkaline) soils. It cannot grow in the shade.

Ethnomedicinal Uses: The spherical underground tubers, with their sweet nutty flavor, are consumed fresh, dried, and in roasted forms. Fresh tubers are also soaked in water and processed to yield a refreshing milk-like beverage in Northern Nigeria and Namibia. In Spain, the nutritional drink is called "horchata de chufa." It is fermented in many parts of West Africa to produce an alcoholic drink. The oil, which is rich in oleic (65.55%), palmitic (16.32%), and linoleic (12.13%) acids is produced commercially in the Valencia region of Spain as a substitute for olive oil, as a nutraceutical agent, and as a major ingredient for high-quality cosmetics. According to the online encyclopedia, Wikipedia, tigernuts have excellent nutritional qualities, with a fat composition similar to olives and a rich mineral content, especially phosphorus and potassium. Since the oil has a predominance of the unsaturated fatty acids (82%) against only 18% saturated fatty acids, it is useful as a dietary supplement for people with high cholesterol. It can also be used to replace milk in the diet of people intolerant to lactose to a certain extent. Its ethnomedical use is for the treatment of stomach, bowel disorders, and inflammatory diseases.

Constituents: Tigernut contains carbohydrates, flavonoids, minerals, phytosterols, tocopherols, and tocotrienols and various nutrients. The oil is composed of seven major triacylglycerols (TAG) classes, with C54:3 (29.00%) and C52:2 (27.82%) dominating. Oleoyl chain primarily occupied both sn-1/3 (52.68%) and sn-2 (77.62%) positions in the tigernut oil. It has a total tocol content of 120.10 μg/g, dominated by α-tocopherol (86.73) and

β-tocopherol (33.37 μg/g). The total 4-desmethylsterol content is 986 μg/g, dominated by β-sitosterol (517.25 μg/g) and stigmasterol (225.25 μg/g).[555]

Pharmacological Studies: Most of the biological studies on tigernut have been on its nutritional properties. The rhizomes are used for chewing, in preparing the white, jelly-like, tigernut milk recommended as a substitute for dairy milk and in therapeutic diets for diabetes, hypercholesterolemia, and chronic indigestion. Because of its high content of vitamin E, it helps slow down the aging of the body cells. In cosmetics preparations, it improves the elasticity of the skin and reduces wrinkles.[556] The related *Cyperus rotundus* has been evaluated for its antibacterial, anti-inflammatory, antidiabetic, and antioxidant activities with positive results.[557] The oil from *C. esculentus* has been successfully used as a source of feedstock for the synthesis of a relatively cheap and nontoxic fatty hydroxamic acid (FHA), which has remarkable antioxidant and free-radical-scavenging activity.[558] FHA was synthesized from the seed oil of *C. esculentus* via a two-step reaction system; the FHA was later subjected to an antioxidant activity test using 2,2-diphenyl-1-picyrl hydrazyl assay to establish the biological activity of the FHA.

Trichilia

Overview

Trichilia emetica is native to the savanna belt and open woodland of Africa. Two subspecies are known; subspecies *emetica* occurs in the open savanna woodlands subject to grass fires, while subspecies *suberoosa* is generally confined to the more fertile soils of the river banks and seasonally flooded river beds. The seed of *Trichilia emetica* yields two kinds of oil: "mafura oil" from the fleshy seed envelope (sarcotesta) and "mafura butter," also called "mafura tallow," from the kernel. Mafura oil is edible, but mafura butter is unsuitable for consumption because of its bitter taste. It is used in soap and candle making, as a body ointment, wood oil, and for medicinal purposes. The seed cake is only useful as a fertilizer. In some areas, the seed cover is chewed as a substitute for the Kola nut. The plant yields fats, resin, tannins, and a bitter principle that is related to calicedrin. The bark of the related species, *T. heudelotti*, showed the presence of pyrocathechuic acid, a bitter principle, and sterols.[559] The seeds of *Trichilia* species contain a fat (40%–60%), which consists of oleic, palmitic, and linoleic acids. Also isolated from the roots of the plant are four pregnanes: 1-methoxy-pregnan-17(*R*)-1,4-dien-3,16-dione, 1-methoxy-pregnan-17(*S*)-1,4-dien-3,16-dione, 2,3-seco-pregnan-17(*S*)-2,3-dioic acid-16-oxo-dimethyl ester, and 2*a*,3*a*,16*a*-trihydroxy-5*a*-pregnan-17(*R*)-20-yl acetate; three androstanes: 1-methoxy-androstan-1,4-dien-3,16-dione, 2,3-seco-androstan-2,3-dioic acid-16-oxo-dimethyl ester, and 3-methoxycarbonyl-2,3-seco-androstan-3-oic acid-16-oxo-2,19-lactone, together with some pregnane derivatives.

Pharmacognostical Profile

Botanical Name: *Trichilia emetica* Vahl.

Synonyms: *Trichilia umbrifera* Swynn.; *Trichilia somalensis* Chiov.; *Trichilia grotei* Harms.; *Trichilia roka* Chiov.; *Trichilia jubensis* Chiov.

Family: Meliaceae

Common Names: Mafura oil, mafura tallow

African Names: Arabic: safsafa; Ashanti: chele, yofunosi, kisiga, asabrabise; Bari: korillon; Hausa: jan saiwa; Dinka: apolgum; Igbo: ubenwenwe (*T. lanata*); Tigre: gumeh; Yemen: roqah, rugah, rogah, roka; Somali: goro-mas; Kilia: mukeko, mukeka; Cinyanja: msikitsi, mwavi; Chindao: musikdidzi, musikiri, misikiri; Singuni: nkhulu or umkuhlu; Swaziland: mhisi; Swahili: miti-mai, mnwamaji, mnwamai; Kikuyu: mururi; Tswana: tsandi, mosikiri; Xhosa: umkhulu; Kamasia: sorget, sok; Meru: musunui; Kisi: omenyakige; Bemba: mushikishi; Lozi (Tonga): musikili; Nyanya: msikizi; Diola: bouriete; Mandigo: queco; Yoruba: ashapa; Zulu: vungu, umkhulu

Description: A small deciduous evergreen tree 2–30 m high, up to 90 cm in diameter. The bark is gray to brown, smooth to rough, and the twigs are corky. It has deep reddish-pink slash becoming brownish and paler inward, colorless or off-white later. The leaves are pinnate, with 3–5 pairs of leaflets, opposite or almost opposite, and a terminal leaflet; the distal leaflets are larger, narrowly elliptic, or obovate to elliptic, oblong or ovate, 1.5–15 cm long, 1–6.5 cm wide, the apex obtuse or notched; thinly pubescent, dark glossy green above, sometimes glabrous, 9–14 pairs of lateral veins. It produces yellow flowers, 5-merous, monoecious but with very little external differences between sexes; borne in leaf axils or on older twigs. The calyx is cup-shaped, deeply lobed almost to the base, the lobes ovate, 1.57 mm long, 2–5 mm wide. The fruits are characteristically fig-shaped, orange or purple-red in color, glabrous, usually opening by four valves and containing seeds embedded in an orange-colored aril.[1]

Habitat and Distribution: *Trichilia emetica* is native to the savanna belt and open woodland of Africa. Two subspecies are known: subspecies *emetica* occurs in the open savanna woodlands subject to grass fires, while subspecies *suberoosa* is generally confined to the more fertile soils of the river banks and seasonally flooded river beds. The species is distributed widely in the tropical savannas and occurs from Liberia to Congo, and parts of southern Africa. The subspecies *emetica* is found mainly in the eastern parts of Africa and occurs in Ethiopia, Somalia, Zaire, Uganda, Kenya, Tanzania, Zambia, Zimbabwe, Malawi, Mozambique, Botswana, Angola, Namibia, and Swaziland. The other subspecies *suberoosa* occurs in the west African region, and has been located in Gambia, Guinea Bissau, Guinea, Mali, Ivory Coast, Burkina Faso, Ghana, Togo, Benin, Nigeria, and Cameroon.

Culinary (Food) Uses: The seeds are edible after removal of the seed coat and the seed arils are cooked as vegetables or crushed to yield a milky juice that is added to spinach for flavor.

Ethnomedicinal Uses: In West Africa, the pounded bark is used as an external application to treat parasitic skin infections and inflammation. The plant is purgative, and the bitter root extract is administered as an enema for this purpose. An infusion of the stem bark is also used as a purgative in many parts of the continent. The plant is considered emetic in high doses, and has also been used as an antiseptic, general tonic, and in the treatment of bronchial inflammation. It enjoys a folk reputation as a traditional remedy for cirrhosis, stomachaches, dysmenorrhea; hepatitis, gastric affections, fever, and as an antiepileptic, as well as for cough, bronchial trouble, gonorrhea, syphilis; and the leaves have been used against scabies, malaria, hypertension, burns, intestinal parasites, cutaneous or mouth infections. *Trichilia* species are traditionally used by many cultures for the treatment of many diseases such as asthma, gastric affections, hepatitis, cirrhosis, and dysmenorrhea.

Constituents: The plant yields fats, resin, tannins, and a bitter principle that was shown to be related to calicedrin.[560] The bark of the related species *T. heudelotti* showed the presence of pyrocathechuic acid, a bitter principle, and sterols.[559] The seeds of *Trichilia* species

contain a fat (40%–60%), which consists of oleic, palmitic, and linoleic acids. A meliacine, prieurianine, has been shown to be a constituent of the Nigerian plant, *T. prieriana*. The roots of the plant have been found to contain four pregnanes: 1-methoxy-pregnan-17(*R*)-1,4-dien-3,16-dione, 1-methoxy-pregnan-17(*S*)-1,4-dien-3,16-dione, 2,3-seco-pregnan-17(*S*)-2,3-dioic acid-16-oxo-dimethyl ester, and 2*a*,3*a*,16*a*-trihydroxy-5*a*-pregnan-17(*R*)-20-yl acetate; three androstanes: 1-methoxy-androstan-1,4-dien-3,16-dione, 2,3-seco-androstan-2,3-dioic acid-16-oxo-dimethyl ester, 3-methoxycarbonyl-2,3-seco-androstan-3-oic acid-16-oxo-2,19-lactone, together with some pregnane derivatives.[561]

Pharmacological Studies: The seeds of *Trichilia* were found to be purgative and emetic, the seed cake has been shown to be toxic to cattle. Extracts of the plant showed positive effects in a dose-dependent manner against diarrhea induced by castor oil in experimental mice. It also showed good antimicrobial activity against all tested Gram-negative and Gram-positive bacterial strains. It was shown that experimental bacteria strains were more sensitive to the *Trichilia* extract compared to the ciprofloxacin used as a positive control.[376] Other studies on this plant includes anti-infective, anti-inflammatory, antischistosomal, antiplasmodial, anticonvulsant, antitrypanosomal, antioxidant, antitussive, antimutagenic, wound-healing and hepatoprotective properties. Limonoids isolated from the stem bark exhibited selective inhibitory activity toward DNA repair-deficient yeast mutants and exerted antifungal, bactericidal, antiviral, antifeedant, and growth-regulating properties.[562]

Turmeric

Overview

Turmeric is an introduced cultivated crop, which consists of the primary and secondary rhizomes of *Curcuma longa*. It has remarkable antioxidant and anti-inflammatory properties and has been used in clinical medicine for the treatment of various inflammatory diseases. Turmeric contains a group of compounds called curcuminoids, which include curcumin (diferuloylmethane), demethoxycurcumin, and bisdemethoxycurcumin. The best-studied compound is curcumin, which constitutes 3.14% (on average) of powdered turmeric. In addition, other important volatile oils include turmerone, atlantone, and zingiberene. It also contains proteins, resins, and carbohydrates.

Pharmacognostical Profile

Botanical Name: *Curcuma longa* L.
Synonym: *C. domestica* Val.; *Stissera curcuma* Raeusch.; *Amomum curcuma* Jacq.
Family: Zingiberaceae
Common Name: Turmeric
African Names: Shambala: kitambwe: Swahili; mandano, manjano, kilunga kuku
Description: Turmeric consists of the rhizomes of *Curcuma longa*. They occur as primary and secondary rhizomes. The primary rhizomes are ovate or pear-shaped, while the secondary rhizomes or "fingers" are more cylindrical and lateral. Turmeric has an inner yellowish brown color, with a characteristic odor and slightly bitter taste.[280]



Culinary (Food) Use: It is used as a spice, usually in its dried, powdered form but it is also used fresh, like ginger.

Ethnomedicinal Uses: The plant is employed in West Africa as anthelmintic and as ointment for skin diseases. It is used as an anti-inflammatory agent and applied as an eye wash for conjunctivitis. In West Africa, the powdered rhizome is mixed with flour into a paste applied to the head for the relief of headache. It is also applied as an ointment on the body of smallpox patients and the patients are made to stay out in the sun. The rhizome and the juice are used in Mauritius as an emmenagogue.

Constituents: The plant contains about 5% diaryl heptanoids called curcuminoids. The principal curcuminoids are curcumin (diferuloylmethane), monodes-methoxycurcumin, and dihydrocurcumin. The volatile oil of the plant contains sesquiterpene ketones, borneol, α-phellandrene, and zingiberine.

Pharmacological Studies: Curcumin has anti-inflammatory activity that was found comparable in potency to that of phenylbutazone. It inhibits carrageenan-induced inflammation in rats, and blocks arachidonic acid metabolism via both the cyclooxygenase and the 5-lipooxygenase pathways. The crude drug has antimicrobial, antiprotozoal, and antiinfertility properties.

Srivastava has used ^{14}C-labeled arachidonic acid (AA) to establish that curcuma extract inhibited thromboxane B_2 (TxB_2) production.[602] He showed that less TxB_2 was produced in blood samples treated with curcuma extract when they were allowed to clot. It was also observed that the extract inhibited the incorporation of [^{14}C] AA into platelet phospholipids and deacylation of AA-labeled phospholipids on stimulation with calcium ionosphere A23187.[602] Dixit et al. showed that the extract caused a significant reduction in the ratio of total cholesterol/phospholipid and elevated the HDL-cholesterol/total cholesterol ratio in triton-induced hyperlipidemic rats.[603]

The effects of turmeric in liposomal and lipid peroxidation and peroxide-induced DNA damage have been investigated. Curcumin and the aqueous extract of curcuma were found to be an effective antioxidant. Curcumin showed activity comparable to that of butylated hydroxyanisole (BHA). It has been shown that the inhibition obtained using aqueous extract, incorporated into the liposome itself, at 300 ng/μg protected DNA against peroxidation injury at 100 ng/μg. Curcumin and the crude extract have also been shown to be cytotoxic to lymphocytes and Dalton's lymphoma cells at concentrations of 4 and 0.4 mg/mL, respectively, and also inhibited the cell growth in Chinese hamster ovary cells at the same concentrations. Curcumin possesses selective phototoxic effect on bacteria.

Lee and Lin have shown that curcuma extract had mild antimutagenic activities against benzo[α]pyrene-induced mutation in salmonella/microsomal system.[604] It also inhibited mutagenicity induced by several environmental mutagens, including bidi and cigarette condensates, tobacco, and dimethyl benzo-[α]anthracene in a dose-dependent manner.

Curcumin has cortisone-like inhibitory activity on pro-inflammatory kinases in the healing of wounds. In an experiment on the healing of superficial and penetrating corneal wounds in albino rabbits, aqueous extract (2.8%) of curcuma definitely improved the healing of superficial corneal wounds when compared with the effect of placebo and preservative eye drops and also markedly reduced the tensile strength of corneal wounds. The 1:1 w/v aqueous extract has been shown to antagonize the toxic action of cobra, *Naja-naja siamensis*, neurotoxin possibly via direct inactivation of the toxin.[606,607] The plant extract also possesses proteolytic activity, which was shown not to be a likely mechanism for its antagonism to the cobra neurotoxin.

The antitumor properties of curcuma may be due to the presence of β-elemene, which has been found to be one of the cytotoxic constituents of the plant. It showed 100% anti-infertility action in albino rats at a dose of 100 mg/kg. The petroleum ether extract showed 80% anti-infertility activity in the same assay and also caused resorption of the implants. In a gastric ulcer study, native, intact (TrPP) and modified, low-molecular-weight (MTrPP) forms of pectic polysaccharides isolated from turmeric were evaluated for ulcer-preventive potentials in *in vitro* and *in vivo* models.[562] The result indicated that MTrPP possessed significantly better ulcer-preventive property than TrPP, inhibiting ulcer scores up to 85%. Results were substantiated by effective muco-protection, H^+, K^+-ATPase downregulation, inhibition of *H. pylori* growth/adherence, higher antioxidant/cytoprotective mechanisms. The two polysaccharides were found to differ in their molecular weights and structural characteristics with different sugar compositions and side chain ratios. MTrPP was found to be rich in galacturonic acid (687 mg/g; TrPP—544 mg/g) and galactose (52.9%; TrPP—21.7%). The results were substantiated by NMR/FTIR data indicating the presence of homogalacturonan and rhamnogalacturonan-1 containing galactans. The galactans may reduce inflammation-induced ulcerations by virtue of their known binding affinity to inflammatory marker (galectin-3).[563]

Clinical Properties: Turmeric is a spice used as a food condiment in many countries. It has anti-inflammatory activity that is comparable in potency to that of phenylbutazone. A proprietary preparation known as Temoe–Lawak–Singer (RVG 08637) used on various inflammatory conditions has been shown to reduce both the serum and liver cholesterol in rats. RVG 08637 consists of a mixture of extracts of *Curcuma* species and *Rhammi purshianae* and is known to have choleretic and chologougic activity in humans.

An ethanol extract of curcuma and the ointment of curcumin were found to produce remarkable symptomatic relief in patients with cancerous lesions. Reductions in smell were noted in 90% of the cases, and in almost all the cases, there was reduction in itching. It was also observed that dry lesions occurred in 70% of the cases, and 10% of the patients had a reduction of lesion size and pain.[605] The observed effects continued in many of the patients for several months. The rhizomes of curcuma have been investigated for antioxidant, anti-inflammatory, insect antifeedant, antiviral, cytotoxic, and trypanocidal activities and in the treatment of Alzheimer's disease, cancer, arthritis, and other clinical disorders.[564] Curcuminoids, labdane, halimane, and clerodane-type diterpenoids, considered the major biological constituents of *Curcuma* genus, have been incorporated into many nutraceuticals or dietary supplements[565] and as a potential antitumor drug.[566,608]

Toxicity and Adverse Reactions: Turmeric is used in various parts of the world as a food item and no incidence of toxicity has been recorded. In the controlled clinical studies by

Kuttan et al., only one patient reported adverse effects.[567] Feeding experiments with raw turmeric and the alcoholic extract at very high doses of up to 2–5 g/kg and 300 mg/kg, respectively, resulted in no apparent toxicity to rabbits, guinea pigs, and monkeys.[568]

Ugu: Fluted Pumpkin

Overview

Ugu, *Telfairia occidentalis* (family Cucurbitaceae), is a vegetable that originated from south-eastern Nigeria and it is cultivated as a crop of commercial importance in Nigeria, other West African countries (Ghana, Benin, Togo, and Sierra Leone), and Cameroon. The plant produces luxuriant edible green leaves, which are rich in minerals (iron, calcium, phosphorus, magnesium, potassium, manganese, copper, and zinc) and vitamins. The stems of the plants have branching, long twisting tendrils and the leaves are divided into three to five leaflets with the terminal leaflets up to 15 cm long. Fluted pumpkin is majorly cultivated for its leaves and used as vegetable in soups and stews, as a blood tonic, and as a potherb. The seeds can be eaten whole by boiling or used for soup thickener and vegetables. The leaves contain a rich pool of essential oils, polyphenols, proteins, minerals (such as iron, potassium, sodium, phosphorus, calcium, magnesium, and zinc), and vitamins (such as thiamine, riboflavin, nicotinamide, and ascorbic acid). The essential amino acid content has been reported as comparable to those of important legumes. The seed contains 29%–47% oil and 30%–35% protein; the protein is deficient in the sulfur amino acid, and the oil consists mainly of unsaturated fatty acids, which form 61% of the lipid content.

Fluted pumpkin leaves possess a remarkable ability to suppress or prevent the production of free radicals and scavenge already-produced free radicals, lower lipid peroxidation status, and elevate antioxidant enzymes (such as superoxide dismutase and catalase) both *in vitro* and *in vivo*, as well as possess anti-inflammatory activity. They showed hypolipidemic effect, antimicrobial activity, antidiabetic, and antiplasmodial properties. The root extract has antibacterial activity against *Staphylococcus aureus*, *Streptococcus pyogenes*, *Shiegella dysenteriae*, and *Kliebsiella pneumoniae*. The plant has shown some promise in the regeneration of testicular damage and also increases spermatogenesis in animals. It was also found that a diet containing 15% *Telfairia occidentalis* seeds showed the inhibition of the induction of experimental andropause. Andropause, a prevalent pathology of men, results from an imbalance in steroid hormone concentrations that is often associated with aging, and reduces the quality of life of the sufferer. Perhaps the greatest value from fluted pumpkin is the antianemic and antioxidant properties of the leaves as evidenced from many observational studies, and the antiandropause and antihyperlipidemic activity of the seeds.

Pharmacognostical Profile

Botanical Name: *Telfairia occidentalis* Hook.f.
Related Species: *Telfairia pedata* (Sm. ex Sims) Hook.
Family: Cucurbitaceae
Common Names: Fluted pumpkin, fluted gourd, oysternut (*T. pedata*)
African Names: Igbo: ugu; Yoruba: iroko, krobonko; Edo: umeke; Sierra Leone: pondokoko, oroko, gonugbe; Efik (Nigeria): ubong; Urhobo (Nigeria): umee

Description: Ugu is a perennial, dioecious herb climbing by coiled, often branched tendrils to a height of more than 20 m; the root system ramifying in the top surface of the soil; the stem angular, glabrous, becoming fibrous when old. The leaves are arranged spirally, pedately compound with 3–5 leaflets; the stipules absent; the petiole (2–)4–11(–15) cm long; the leaflets with petiolules 0.5–3.5 cm long, the central one largest, up to 15(–19) cm × 10(–12) cm, the lateral ones asymmetrical, usually dentate in the upper two-thirds, sometimes scabrid underneath, three-veined from near the base. The male inflorescence an axillary raceme up to 3(–5.5) cm long, on a peduncle up to 25 cm long, with at the base of the peduncle one long-pedicellate flower blooming long before the others; female flowers solitary in leaf axils. Flowers 5-merous, cream colored, the pedicel up to 4 cm long, the receptacle campanulate, the sepals triangular, up to 5 mm long, the petals free, oblong, fringed; the male flowers with three stamens, two 4-locular and one 2-locular, with large reddish connective; the female flowers similar to male flowers but with inferior, cylindrical, three-celled ovary and three large, heart-shaped stigmas. The fruit of the ugu is a drooping, large, 16–105 cm (6.3–41.3 in.) in length, and an average of 9 cm in diameter, weighing up to 6 kg, with 10 prominent ribs, pale green and covered with white bloom wax, fruit pulp yellow, many-seeded. The seeds (up to 196 in a fruit) are compressed, ovoid, up to 4.5 cm long, black or brown-red. The seedling with hypogeal germination, first develops a taproot and then numerous, spreading axillary roots; the epicotyl 5–12 cm long; the cotyledons planoconvex and fleshy. The various cultivars of *Telfairia occidentalis* are distinguished by seed color, thickness of vine, size of leaf, growing vigor, days to flowering and succulence. The two main cultivars in Nigeria are *ugu-ala*, characterized by succulent, broad leaves, small black seeds, thick stem, and slow growth and *ugu-elu* which has a high growth rate, large brownish seeds with high viability, and thin stem with small leaves. The large succulent leaves of ugu-ala make this cultivar a commercial vegetable in high demand, while the fast emergence and high growth rate of "ugu-elu" is preferred by farmers because of quick returns.[569] The seed is often polyembryonic, which is useful for multiplication and in breeding.[570]



Habitat and Distribution: The plant is believed to have originated in south-east Nigeria and it is a favorite vegetable among the Igbo people. It occurs in the forest zone of West and Central Africa. It is a cultivated crop. It does not appear to be known or cultivated outside West Africa.

Culinary (Food) Use: The tender shoots, succulent leaves, and immature seeds of the fluted pumpkin are cooked and consumed as a vegetable. The leaves are used alone or

together with okra and dika nut (ogbono), or egusi seeds for the preparation of soups. The fruits have been used to prepare marmalade.[571]

Ethnomedicinal Uses: The high nutritional value of fluted pumpkin is recognized in traditional medicine and the plant is frequently recommended as part of the treatment of severe anemia and during convalescence.[572] It is used in traditional medicine to treat sudden attack of convulsion, malaria, and diabetes, and it also plays a vital and protective role in cardiovascular diseases.

Constituents: The leaves contain essential oils, polyphenols, minerals (such as iron, potassium, sodium, phosphorus, calcium, magnesium, and zinc),[573] and vitamins (such as thiamine, riboflavin, nicotinamide, and ascorbic acid). Root contains cucubitacine, sesquiterpene, lactones, and phytosterols. The essential amino acids content has been reported as comparable to those of important legumes.[574] The identified amino acids include alanine, aspartate, glycine, glutamine, histidine, lysine, methionine, tryptophan, cystine, leucine, arginine, serine, threonine, phenylalanine, valine, tyrosine, and isoleucine. The seed contains 29%–47% oil and 30%–35% protein; the protein is deficient in the sulfur amino acid, and the oil consist mainly of unsaturated fatty acids, which form 61% of the lipid content.

Pharmacological Studies: Whole leaves and leaf extracts of ugu have been shown to possess a remarkable ability to suppress or prevent the production of free radicals and scavenge already-produced free radicals, lower lipid peroxidation status, and elevate antioxidant enzymes (such as superoxide dismutase and catalase)[575] both *in vitro* and *in vivo*,[576] as well as possess anti-inflammatory activity. The fluted pumpkin showed hypolipidemic effect, antimicrobial activity, and antiplasmodial properties. It has been shown that the blood schizontocidal activity of the root extract is comparable to that of chloroquine.[577] It has also been found active against anemia,[578] chronic fatigue,[579] and diabetes.[580] In a comparative study of the vitamin A content and consumption pattern of some green leafy vegetables (which includes *Telfairia occidentalis)* among pregnant women in Calabar, Nigeria, it was found that *ugu* has the highest vitamin A content among the vegetables tested and at a level adjudged adequate to sustain their vitamin A requirement.[581] The root extract has been shown to have antibacterial activity against *Staphylococcus aureus*, *Streptococcus pyogenes*, *Shiegella dysenteriae*, and *Kliebsiella pneumoniae*.[582] The plant has shown some promise in the regeneration of testicular damage and also increases spermatogenesis in animals.[583] In another study, it was found that a diet containing 15% *Telfairia occidentalis* seeds is useful in the inhibition of the induction of experimental andropause.[584] Andropause, a prevalent pathology of men, results from an imbalance in steroid hormone concentrations that is often associated with aging, and reduces the quality of life of the sufferer. The test diet containing fluted pumpkin seeds resulted in a modest reduction of biochemical castration and an improvement in the secretory capacity of the testes of the test rats, relative to the control group that received the hormones but was placed on a normal diet. *T. occidentalis* seeds-incorporated diet may be useful in inhibiting the induction of andropause in human.

Velvet Bean: Lacuna Bean

Overview

Lacuna bean consists of *Mucuna pruriens* and related species. It is used in West Africa as a soup thickener. The seeds contain protein (15%–30%), amino acids, fixed oils (8%),

calcium, fiber, and vitamins. It yields L-dopa (L-3,4-dihydroxyphenylalanine) from which dopamine is prepared, an important medicine to relieve the effects of Parkinson's disease and DMP (*N*-dimethyltryptamine), which has hallucinogenic properties. The plant has antidiabetic and anti-inflammatory properties and is effective in the treatment of male sexual dysfunction. The plant is notorious for the extreme itchiness it produces on contact with the pod due to the presence of serotonin on its surface. It is an ingredient in several proprietary dietary supplements as an antidepressant, libido booster, or testosterone enhancer.

Pharmacognostical Profile

Botanical Name: *Mucuna pruriens* (L.) DC.

Synonyms: *Carpopogon pruriens* (L.) Roxb.; *Dolichos pruriens* L.; *Mucuna aterrima* (Piper & Tracy) Merr.; *Mucuna axillaris* Baker; *Mucuna cochinchiniensis* (Lour.) A. Chev.; *Mucuna nivea* (Roxb.) Wight & Arn.; *Mucuna prurita* (L.) Hook.; *Stizolobium pruritum* (Wight) Piper; plus five others

Related Species: *Mucuna pruriens* var. *hirsuta* (Wight & Arn.) Wilmot-Dear; *Mucuna pruriens* var. *pruriens* (L.) DC.; *Mucuna pruriens* var. *utilis* (Wall. ex Wight) L.H.Bailey.

Family: Leguminosae

Common Names: Lacuna bean, Bengal velvet-bean, black velvet bean, buffalo bean, hell fire bean, itchy bean

African Names: Igala (Nigeria): inyelekpe; Igbo (Nigeria): ukpo; Kiswahili: upupu; Malawi: chitedze; Yoruba: yerepe or warapa; Madagascar: aga

Description: The plant consists of three related species, noted for the extreme itchiness they produce on contact, particularly with the young foliage and seed pods. They differ significantly in their morphological characteristics. Detailed descriptions of the three species are available in PROTA. The subject species *Mucuna pruriens* (L.) DC is an annual, climbing shrub with long vines that can reach over 15 m in length. The young plant is almost completely covered with fuzzy hairs, but when older, it is almost completely free of hairs. The leaves are tripinnate, ovate, reverse ovate, rhombus-shaped, or widely ovate. The sides of the leaves are often heavily grooved and the tips are pointy. In young plants, both sides of the leaves have hairs. The stems of the leaflets are 2–3 mm long. Additional adjacent leaves are present and are about 5 mm long.[585]

The flower heads take the form of axially arrayed panicles. They are 15–32 cm long and have two or three, or many flowers. The accompanying leaves are about 12.5 mm long, the flower stand axes are from 2.5 to 5 mm. The bell is 7.5–9 mm long and silky. The sepals are longer or of the same length as the shuttles. The crown is purplish or white. The flag is 1.5 mm long. The wings are 2.5–3.8 cm long. In the fruit ripening stage, a 4–13-cm-long, 1–2-cm-wide, unwinged, leguminous fruit develops. There is a ridge along the length of the fruit. The husk is very hairy and carries up to seven seeds. The seeds are flattened uniform ellipsoids, 1–1.9 cm long, 0.8–1.3 cm wide, and 4–6.5 cm thick. The hilium, the base of the *funiculus* (connection between placenta and plant seeds), is a surrounded by a significant arillus (fleshy seeds shell). It bears white, lavender, or purple flowers. Its seed pods are about 10 cm long and are covered in loose, orange hairs that cause a severe itch if they come in contact with skin. The seeds are shiny black or brown drift seeds.



Habitat and Distribution: *Mucuna pruriens* is found occurring naturally in tropical parts of Africa, Asia, and the Caribbean.

Culinary (Food) Use: Velvet bean is used as a soup thickener and general tonic.

Ethnomedicinal Uses: *Mucuna* seeds are used in traditional medicine mainly for the treatment of diabetes and male sexual dysfunction, and as a soup thickener for general weakness. The pod hairs mixed with syrup, molasses, or honey are taken as an anthelminthic and anti-inflammatory. Boiled seeds are occasionally eaten as a pulse, and boiled immature pods and young leaves as vegetables. It enjoys a reputation as a potent aphrodisiac and source of vitamins and minerals.

Constituents: *Mucuna pruriens* seeds contain protein (15%–30%), amino acids, fixed oils (8%), calcium, fiber, and vitamins. Two important nonprotein amino acids are found in the seed and in smaller amounts in the stems and leaves: L-dopa (L-3,4-dihydroxyphenylalanine) from which dopamine, an important medicine to relieve the effects of Parkinson's disease, is prepared, and DMP (*N*-dimethyltryptamine), which has hallucinogenic properties. The L-dopa content varies from 1.6% to 3.3% and is sufficiently high both as a phytomedicinal and for commercial extraction of the active constituent. The seed also contains a number of alkaloids, the most important of which are mucunaine, prurienine, and serotine. The stinging hairs of the velvet bean, used as an anthelmintic, contain a pruritogenic, proteolytic enzyme and granular matter, tannic acid and resin.[1] The concentration of L-dopa in the defatted *Mucuna* meal was greatly increased when extracted with supercritical carbon dioxide, performed in a laboratory scale unit at 40°C and 60°C over a pressure range from 150 to 250 bar. A constant flow rate of CO_2 close to 3 mL/min was maintained. This finding is industrially useful in the production of L-dopa from *Mucuna* without the problem associated with residual solvent after extraction of plant materials for clinical use.[586]

Pharmacological Studies: The chemical compounds responsible for the itch are a protein, mucunain, and serotonin. The seed powder of *Mucuna pruriens* has been clinically

assessed in several studies for its application in the treatment of Parkinson's disease.[587,588] The clinical effects of *Mucuna* seed powder and levodopa (L-dopa) pharmacokinetics were evaluated following two different doses of *Mucuna* preparation and were compared with standard L-dopa/carbidopa (LD/CD). In the study, eight Parkinson's disease patients with a short duration L-dopa response and on-period dyskinesias completed a randomized, controlled, double-blind crossover trial. Patients were challenged with single doses of 200/50 mg LD/CD, and 15 and 30 g of *Mucuna* preparation in randomized order at weekly intervals. L-Dopa pharmacokinetics were determined, and Unified Parkinson's Disease Rating Scale and tapping speed were obtained at baseline and repeatedly during the 4 h following drug ingestion. Dyskinesias were assessed using modified AIMS and Goetz scales. The 30 g *Mucuna* preparation when compared with standard LD/CD led to a considerably faster onset of effect (34.6 vs. 68.5 min; P = 0.021), reflected in shorter latencies to peak L-dopa plasma concentrations. Mean on time was 21.9% (37 min) longer with 30 g *Mucuna* than with LD/CD (P = 0.021); peak L-dopa plasma concentrations were 110% higher and the area under the plasma concentration *v* time curve (area under curve) was 165.3% larger (P = 0.012). No significant differences in dyskinesias or tolerability occurred. These findings suggest that the rapid onset of action and longer on time without concomitant increase in dyskinesias on *Mucuna* seed powder formulation indicates that this natural source of L-dopa might possess advantages over conventional L-dopa preparations in the long-term management of PD.

The antidiabetic activity has been established in a rat model. Chronic administration of the alcoholic extract of *Mucuna pruriens* seeds resulted in a significant dose-dependent reduction in the blood glucose level ($P < 0.001$). Acute toxicity studies indicated that the extract was relatively safe at low doses; although some adverse reactions were observed at higher doses (8–32 mg/kg body weight), no death was recorded. Furthermore, oral administration of *M. pruriens* seed extract also significantly reduced the weight loss associated with diabetes.[589] In another study, the effect of ethanolic seed extract of *M. pruriens* on mitochondrial dysfunction and the DNA damage in hyperglycemic rat epididymal spermatozoa was investigated.[590] Significant reduction in the sperm count, motility, viability, and significant increase in the number of abnormal sperm in STZ compared to the control group was observed. STZ rat sperm showed significant increase in LPO and DNA damage. Both the enzymic and nonenzymic activities were decreased; MMP and the mitochondrial functions were severely affected in the STZ group. The diabetic rats supplemented with *M. pruriens* showed a remarkable recovery in antioxidant levels and reduced LPO with well-preserved sperm DNA. MMP and mitochondrial function test were also preserved in STZ + MP rat sperm. The findings clearly demonstrated the potency of *M. pruriens* to reduce the diabetic-induced sperm damage induced by oxidative stress (OS). It is inferred from these results that a similar mechanism may account for the effect of *Mucuna* in humans. The plant is used as in the treatment of male sexual dysfunction. It is also an ingredient in several proprietary dietary supplements for its established antidepressant, libido boosting and testosterone enhancement effects.

Agriculture: Propagation of *Mucuna pruriens* is mostly by seed. The seed requires no scarification, but dry seed requires soaking in water for 24 h. The germination rate of fresh seed is 90%–100%, declining with time. Seed stored in a cool dry place remained viable for about 2 years, but seed stored in a sealed jar for 3 months lost its viability. Germination takes 4–7 days. It is cultivated more for its soil fertility benefits than as a medicinal plant. In India and other parts of Asia, the plant is cultivated commercially.

Commerce: *Mucuna* is a major of commodity in international medicinal plant trade but it is neither cultivated in large scale nor exported in any significant manner in the continent.

Annual world seed production has been estimated to be 900,000 tons. Small quantities exported from Cameroon in 2011 was sold at US$ 2.5 per kg.

Wild Olive

Overview

The African olive or wild olive is similar in all respects to the Mediterranean olive tree. It has not been domesticated as the European olive tree but it is nonetheless cultivated for its valuable oil, leaves, and the edible blue-black fruit that occurs in drupes. Olive oil is valuable edible oil used as an emollient and as a dietary supplement. The leaves possess antihypertensive activity. There are some commercial formulations with olive leaves alone or in combination with other herbs for the clinical treatment of hypertension.

Pharmacognostical Profile

Botanical Name: *Olea europaea* L. subsp. *africana* (Mill.) P.S.Green

Synonyms: *Olea pallida* Salisb.

Family: Oleaceae

Common Name: Olive tree, olea, wild olive

Description: The olive tree yields evergreen leaves that are employed for the treatment of hypertension. The plant is native to the Mediterranean region where it is cultivated both for its valuable oil and for the leaves. It produces edible blue-black fruit (2–3 cm length) that occurs in drupes. The olive tree grows to a great age but seldom exceeds 12 m in height. The leaves are leathery with scale-like hairs on the underside.[534]

Culinary (Food) Use: Olive oil is valuable edible oil used as an emollient and as a dietary supplement.

Ethnomedicinal Uses: The leaves and bark extracts have been used as a remedy for scrofula and intermittent fever, and a weak decoction of the stem is used as a tonic. The fixed oil from the fruits is employed in southern Africa as an astringent for the treatment of diarrhea.

Constituents: The leaf is rich in tannins. A bitter water-soluble glucoside called oleorepein has been shown to be present in the bark, leaves, and fruits.[591] The seed is the source of the commercially important olive oil, which consists of glycerides of oleic acid (70%–80%), with the glycerides of palmitic, stearic, and linoleic acids being minor components.

Pharmacological Studies: The aqueous extract of olive leaves has been shown to possess significant hypotensive activity in rats.[592] The antihypertensive property of olive leaves may be due to the presence of oleuropein. Several studies have shown that extracts of olive leaves are able to achieve extended and always reproducible reductions in blood pressure, as well as spasmolytic actions on the smooth musculature.[609,610] The effects were observed to be less marked in rats than in cats. Extracts of the leaves also exhibited direct relaxant action on smooth muscles, dilated the bronchi, and improved blood circulation.[593]

Clinical Application: Weiss[594] recommended olive leaves for labile and medium–severe hypertension. Proprietary preparations are available containing olive leaves, for example, Osvysat (Burger) or in combination with diuretic hydrochlorothiazide and potassium chloride (Olivyysat Compd.). A commercial product, Hyperidyst (Vogel and Weber), exists

that contains olive leaves, raulwolfia, arnica root, and mistletoe. A daily dose of 100 mL of an infusion of the leaves for 20–25 days has been shown to increase daily urine output by 10%–15%, with a concomitant decrease in blood uric acid levels and an increase in the urinary uric acid content, without any significant effect on the blood sodium, and chloride levels.[594,595]

A major attribute of the Mediterranean diet, which has been credited with lower incidence of cardiovascular diseases (including hypertension), is the important presence of monounsaturated fatty acids (MUFA) obtained from a high consumption of olive oil. Studies have established the beneficial effects of the consumption of olive oil and polyphenol enriched olive oil in the clinical management of hypertension and related cardiovascular diseases.[611,612]

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