We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Anti-Diabetic Effects of Nigerian Indigenous Plant Foods/Diets

Elizabeth A. Udenta, Ikemefuna C. Obizoba and
Oluwafemi O. Oguntibeju

Additional information is available at the end of the chapter

1. Introduction

Plants play important role in the cycle of nature. This is because life on earth basically depends on them. Plants provide man with all his needs as regards food, shelter, clothing, flavours and fragrance as well as medicine. They are naturally occurring substances that produce almost all the foods that animals as well as humans eat. They have unique potential to make their own food through photosynthesis. All foods that people eat naturally come directly or indirectly from plants. Food is fundamental to human survival. It is basic for averting hunger, satisfying one's palate and maintaining health of every human being. It is used as a status symbol, making people happy, emotionally and socially content, and constitutes a form of cultural expression. It is also used in the performance of various rituals and rites as well as for therapeutic purposes. Culture has a lot of influence on the kind of foods people eat and how they eat them. Traditional foods, was adopted to describe all foods from a particular culture, available from local sources and culturally acceptable as appropriate and desirable foods [1]. The direct and indirect food sources as regards nutrition are simply described as and categorized into two major sources - plant and animal foods, respectively.

Despite the unique role of plant foods as irreplaceable food sources for humans, not all plant foods are available or edible worldwide. Traditional plant foods are those plants grown for food in varying proportions within the farming system operating in any particular locality; or gathered in wild or semi-wild conditions; and are accepted by the community, through custom, habit and tradition as appropriate and desirable foods [1, 2]. They are categorized as those that are consumed as traditional dietary staples and those consumed as components of accompanying relishes and sauces. These traditional foods are often used in sciences as basis for ensuring and optimizing utilization of indigenous foods and their health benefits by individ-

INTECH
open science | open minds

uals, households and communities. The use of plant foods for therapeutic purposes represents one of the biggest human uses of the natural flora of the world [3]. This is because of their health-enhancing bioactive constituents [4]. In the last four decades, there has been considerable interest in resurrecting health-promoting potentials of indigenous plant foods in developing countries and integrating their use into modern medical system. The reasons for this interest are varied and include, i) the negative impact of nutrition transition that increase epidemic of diet-related non-communicable chronic diseases (NCDs) in such regions; ii) high cost of medicare, which put modern health care out of reach of the poor; iii) low adherence to drug prescriptions; and iv) side effects of medicinal plant and herbal medicine extracts and/or preparations, because out of ignorance the consumers consume them as food supplements that are safe at any dose. This is not true for any of the high biologically active medicinal plants. Most of them cannot be consumed habitually as local foods without adverse effects. There was need to challenge reduced interest in and demand for drugs amidst poor health management in these poor regions. Pharmaceutical preparations from medicinal plants created a new expanding market as herbal components of health foods and preventive medicine under "nutraceuticals" or "nutriceuticals". Culhane [5] defined them as products produced from food and sold in pills, powders and other medicinal forms not generally associated with food and are shown to have a physiological benefit or provide protection against chronic diseases. Chronic diseases are largely preventable diseases. Diet-related NCDs are diseases of long duration and generally slow in progression [6]. They are relatively difficult to manage. The high cost and side effects of these supplements still limit their use and have made this approach an unsustainable alternative strategy for chronic disease management and prevention.

Carbohydrate food sources form the greatest percentage [50-60%) of the daily diet for different segments of the population [7]. In Nigeria, starchy staples (cereals, roots/tubers) and legumes constitute the major part of the traditional diets, up to 70% and 25%, respectively [8, 9, 10]. Physiologically, chronic restriction of carbohydrate–rich sources, mainly supplied by plant foods, may pose a serious threat to Nigeria's survival. Diabetics are particularly adversely affected due to misinformation and inability to seek dietetic intervention. Such dietary misinformation has led to starvation and the development of psychosocial problems in diabetics. This is because they feel denied and full of anxiety in anticipation of lifestyle changes [11].

Type 2 diabetes is more common in Nigeria. There was increase in the average prevalence rate from 2.7% [12] to 3.9% [13] and annual increase of 0.3%. Over the years, diet was implicated both as one of the aetiological factors to the development of diabetes [14] as well as a key component in diabetes management [7, 15]. Plant foods are the most important dietary sources to meet the nutritional needs of majority of the population in sub-Saharan Africa and Asian subcontinent [16]. Dietary fibre is a component of carbohydrate in plant foods shown to modulate post-prandial blood glucose after discovery of the "dietary fibre hypothesis" by Cleave [17] and Burkitt et al. [18]. Roles of phytochemicals and antioxidant constituents of plant foods were reported [4]. On this basis, plant foods hold good promise for diabetes

management. There are mounting scientific evidence to date on their various health-promoting properties.

The global concern for the diversification of the uses of plant foods to improve normal and therapeutic nutrition for diabetes control has shifted scientists' interest to enhancing the potential sources of beneficial constituents in plant foods. Plant foods have generated increasing research interest because of their anti-diabetic potentials. There is need to integrate traditional plant foods within local research and innovative systems, in accordance with local needs, food habits and priorities. Currently, documentations on Nigerian indigenous plant foods with anti-diabetic properties are either scattered or lacking. Most reviews on anti-diabetic potentials of plants both locally [19, 20, 21] and internationally [22, 23, 24] were done on medicinal plants. Evidently, not all medicinal plants and herbs used locally are edible. Similarly, not all identified food crops have anti-diabetic potentials. Most of the plants assayed pharmacologically present some difficulties in their dietetic application in humans. They create a gap in optimizing their health-promoting potentials. This paper focuses on some Nigerian indigenous plant foods with anti-diabetic potentials, parts used, their individual effects as reported *in vitro/in vivo* and the extent to which the elucidated parts of the plants were incorporated into the traditional diets for good glycaemic control. The scientific evidence for health benefits of the identified plant foods are summarized in tabular format, and the strength of the evidence is discussed in general terms. Optimization of the utilization of some commonly consumed indigenous anti-diabetic plant foods and their diversification would enhance good diabetes management, improve health of people with diabetes in Nigeria and offer more sustainable health benefits for the indigenous inhabitants.

2. Plant foods in human nutrition and health

Plant foods have remained the ultimate source of nutrients for larger population of the world. They are simply described as irreplaceable food resources for humans, which exclude animal sources. Besides, they are available, affordable and acceptable. They are used for socio-cultural, diabolic, nutritional and therapeutic purposes. These foods contain many chemical compounds needed for metabolic functions in varying proportions. Some of these chemical compounds are non-nutrients that are beneficial to man and others provoke some adverse reactions depending on the levels of intake, interrelationships of nutrients and food habits. Plant foods are classified as cereals, roots and tubers, legumes (pulses, oil seeds and nuts), vegetables and fruits [25]. In order to accommodate these various constituents in foods provided by plants foods, three main categories were established according to the major nutrients they provide. They include the macronutrients (carbohydrate, protein, fat and water), micronutrients (minerals and vitamins) and non-nutrient components (dietary fibre, phytochemicals, anti-nutrients, food toxicants and additives). Metabolic functions of these nutrients and non-nutrients were reviewed by several authors. Bennett [16] observed that plant foods provide the bulk of daily calories for humans [85%] and about 65% of the protein, an assortment of minerals and vitamins, unsaturated fats and phytochemicals in a characteristic manner that reflects current dietary recommendations aimed at promoting health and reducing diet-related

chronic diseases. Thomas [26] concluded that the contribution a food makes to nutrient intake of a person depends on the quantity consumed per 100g, the amount consumed per meal and the frequency of consumption.

Obviously, plant foods have other values related to human nutrition and health apart from their nutritional importance. Plant foods are one of the elements in virtually all cultures, with symbolic and ritualistic values that link language and religion. In many cultures, especially the Asian countries, distinction between food and medicine as therapeutic agents is obscure as the traditional vegetable diets provide the people with disease fighting arsenals that serve both protective/preventive and curative functions. For this reason, foods are widely recognized as the primary health provider.

The bioactive compounds or secondary metabolites are the non-nutrient components in plant foods. They have some nutritional effects and health benefits. They are those substances contained in foods which supply no nutrients. They could contain some compounds that are beneficial to health or toxic to humans and/or act as antagonists to nutrients in foods [27]. They include tannins and other phenolic compounds (phenols, flavonoids, isoflavonoids), saponins, glucosinolates, alkaloids [28, 29], phytate and dietary fibre [30]. These chemical compounds are found in different classes and parts of plant foods in varying amounts. They are more concentrated in plant storage organs (leaves and seeds) than other parts of the plants [22]. These constituents have their individual health-promoting qualities that compel people to combine the different food sources to achieve healthy eating and maintain good health. Several authors [27, 31-35] studied therapeutic potentials and metabolic effects of foods rich in dietary fibre and phytochemical constituents. These include lower risk of colon cancer, promotion of early satiety and normal laxation, moderation of post-prandial blood glucose responses and improved insulin sensitivity, reduction in total and low density lipoprotein (LDL)-cholesterol, regulation of appetite and enhancement of sodium and fluid balance. They are also used to treat constipation and prevent development of diverticulosis and diverticulitis. These are features of a dietary pattern to treat and prevent obesity and its co-morbidities (especially type 2 diabetes mellitus). These two conditions are closely linked because hyperglycaemia and hypercholesterolaemia are well-known cardiovascular risk factors in type 2 diabetes mellitus. Invariably, diets adequate in dietary fibre are usually rich in micronutrients and phytochemicals, and frequently less calorically dense and lower in fat and added sugars. However, environmental factors, cultural food habits and insufficient nutritional information about health benefits of traditional plant foods still pose a problem to healthy food choices. Drewnowski and Gomez-Carneros [29] reported that most of the bioactive compounds are bitter, acrid or astringent and aversive to the consumer and may be wholly incompatible with consumer acceptance. These caused increasing epidemic of diet-related diseases across the regions. They suggest the need to take sensory properties and food preferences into account when advocating for increased consumption and diversification of rich sources of these secondary metabolites in plant foods. The challenge of achieving adequate supply of energy and nutrient intake as well as the health-promoting compounds from plant-based foods/diets without compromising the health of an individual, forms the basis for current dietary recommendations aimed at promoting consumption of plant foods to reduce diet-related NCDs.

3. Plant foods utilization in Nigeria

Nigeria's diverse ethnic groups (over 250] are accommodated under three main ethnic regions - Igbo (in the East), Yoruba (in the West) and Hausa-Fulani (in the North). The country has a beautiful climate, which endows it with very rich biodiversity. A variety of plant foods (maize, rice, sorghum, millet, yam, cassava, cocoayam and legumes) are mainly produced as subsistence food crops in Africa. They are more commonly and widely consumed in Nigeria and other developing countries than in the developed world. They are relatively available, affordable and acceptable. They contribute appreciably to the nutrient intake (energy, protein, fat, vitamins and minerals) of the less developed world. In Nigeria, starchy staples (cereals, roots/tubers) and legumes constitute the major part of the traditional diets (up to 70% and 25%, respectively) [8]. However, cereals are the major staples in the north with much higher intake of animal protein sources (mutton, beef and milk), while starchy roots and tubers are the main staples in the south with relatively more consumption of legumes [10]. These foods contribute appreciably to nutrient intake of southerners [36]. The plant foods are cultivated, gathered wild or are semi-wild.

Roots and tubers are the thickened underground starch storage organs of some plants, propagated vegetatively from the underground stems and their stem cuttings. These edible roots and tubers belong to several families and are formed by both monocotyledons (yams and cocoyams) and dicotyledons (cassava and sweet potatoes) [37]. Cereals are seeds of grass family (Gramineae). Cereals are important crops which serve as industrial raw materials and staple foods for the world over [38]. Cereals are the most widely cultivated and consumed crops globally. World cultivated cereals include wheat, maize, rice, barley, oats, rye, sorghum, millet, wild rice and hungry rice (acha). In Nigeria, the starchy staples (maize, rice, sorghum, millet, yam, cassava, cocoayam and plantain) are utilized in many different forms for preparation of various dishes. Their nutritional importance is that they provide most of the energy, contain high carbohydrate, low protein and appreciable amount of minerals and vitamins, especially the B-complex vitamins. They form the base and usually constitute the major ingredients in the traditional dishes. Some dishes are light and serve as breakfast. Others are solid and frequently made palatable in combination with a variety of legumes and by the addition of palm oil, vegetables and fruits, a range of spices, various sauces and fish/meats. They serve as main meals and eaten later in the day. Processing and preparation methods of these starchy staples and their recipes vary with ethic groups and geographical locations. Each of these staples irrespective of the preparation methods produces a thick paste known as "foofoo" eaten with soups/sauces. These dishes are highly cherished and consumed daily in all parts of Nigeria [39]. These starchy staples are also used to produce complementary foods and local snacks as roasted/fried/baked products or drinks. Some like yam, cocoyam, 'okoho' (*Cissus pulponea* root) are also used to thicken traditional soups.

Legumes are flowering plants in the family Fabaceae (or Leguminosae) that have pods, which contain beans or peas. According to Okafor [40], a list of edible woody leguminous plants, consisting of 150 species covering 103 genera in 48 families was recorded in Nigeria. Legumes rank second to the grasses as source of fodder (for animal) and food for man. The plants are most commonly known as pulses, peas or beans [38]. They contain more protein and less carbohydrate than cereals. There are two main types of legumes: those containing high protein

[25-35%) and oil content [15-45%) and those containing moderate protein [18-24%] and less than 5% oil content. They are oil seeds and pulses, respectively. The most common forms in which legumes are used – they may be cooked alone as pottage, or eaten in combination with any starchy staple of choice. The more widely consumed legumes include cowpea, pigeon pea, soyabean, bambara-groundnut, african yam bean, groundbean and lima bean. It is due to their high protein content that legumes are widely used in combination with cereals for production of nutritious complementary foods for infants and young children both in Nigeria and other developing countries, in both industrial and household levels. This is because legumes are deficient in sulphur-containing amino acids (methionine and cystine) and contain high amount of lysine. Cereals are deficient in lysine and rich in the sulphur-containing amino acids. Legumes play very important culinary roles as soup thickeners. Many of the leguminous seeds are used for thickening soups, sauces and stews in Nigeria [41]. These soup thickeners are condiments/ingredients used in preparation of local soups to alter their consistency and give them special flavour [42]. Traditionally, roots/tubers (yam and cocoayam, 'okoho'), vegetables (okro, 'ogbamu' leaves), legumes (grain legumes/oil seeds and nuts) and fungi are used for thickening soups. Soups made from them are basically prepared with meat and/or fish (when available), oil, vegetables, crayfish, pepper and other condiments and water to obtain watery or thick consistencies depending on their composition. These soups are traditionally consumed in combination with cereals and starchy roots/tubers, processed into a form of paste known as "foofoo". Soups are very important accompaniment to main dishes in Nigeria. Ene-Obong et al. [39] recorded 110 soup recipes out of 322 recipes in all the 6 geo-political zones in Nigeria. The total number of recipes documented reflects the biodiversity of the Nigerian food system. The high viscous property possessed by these leguminous soup thickeners is associated with their dietary fibre content, implicated in attenuation of post-prandial blood glucose and control of lipid metabolism [32].

Vegetables are succulent herbaceous plants that are harvested and eaten whole or in part, raw or cooked as part of a main dish or salad [43]. They can be classified into leaves (green, fluted pumpkin), stems/whole shoot (asparagus, elephant grass, 'achara'), roots (carrot), flowers, immature fruit (fresh corn, okra), mature green fruits (peppers), ripe fruit (tomato), fresh pod (vegetable cowpea), bulbs (onions), tubers (irish potatoes, yams) and fungi (mushrooms, puffballs). There are over 500 known edible vegetables in Africa. Some of these are valued for their bulking effect/thickening power and others may be used as garnishes or spices. Vegetables are generally low in calories and protein. They are valued most for high vitamins and minerals contents. They are low in sodium and rich in potassium, which helps to lower blood pressure [44, 45]. They also contain dietary fibre and phytochemicals (pigments and other compounds that impart flavour to foods), which have heart-disease fighting properties. However, fruits and vegetables consumption is generally low in Nigeria despite their recognition as very important food items to reduce nutrient deficiencies from inadequate intake of minerals and vitamins [46].

Composition of vegetables depends on their species, part of plant and stage of maturity. Spices are vegetables used as ingredients, which contribute to the taste and flavour of foods. The flavour of vegetables is due to sugars, organic acids, minerals salts, volatile sulphur compounds and tannins. The strong flavour of some vegetables (onions and cabbage) is due to their sulphur-containing compounds. Non-volatile acids such as malic, citric, oxalic and

succinic may also contribute to flavour in vegetables. The colour of vegetables depends on the pigments they contain. Spices are known to exert several physiological effects including antidiabetic influence [47]. Anthocyanins impart the blue, purple and red colours to vegetables such as tomatoes, garden eggs and red peppers. Chlorophyll imparts green colour to green leafy vegetables and carotenoids are responsible for the yellow colour in carrots, sweet potatoes and maize. Green leafy vegetables also contain carotenoids but this is masked by the more intense green of chlorophyll. The indigestible dietary fibres – cellulose, hemicelluloses and lignin give the vegetables their characteristics structure. However, some vegetables also contain pectin as storage carbohydrate, which has been linked to reduction of post-prandial hyperglycaemia. Data collection and assessment of commonly consumed foods in all the 6 geo-political zones in Nigeria published by Ene-Obong et al. [39] showed that fruit consumption was conspicuously absent in all the areas. Fruits are the fleshy or dry ripened ovary of a plant, enclosing the seeds. They are commonly eaten raw and used for desserts. Green and yellow vegetables are rich sources of beta-carotene and essential minerals. Most fruits, particularly the citrus species are abundant in vitamin C. These vitamins play antioxidant roles in the body and needs to be supplied in the diet.

4. Diabetes and its public health importance

The term "Diabetes" has been defined by many authors from different perspectives. However, the similarity in these definitions is that diabetes is a chronic metabolic disorder, characterized by high blood glucose (hyperglycemia), associated with impaired carbohydrate, fat and protein metabolism, resulting from either insufficient or no release of insulin by pancreas in the body [48, 49]. Diabetes mellitus is a chronic life-long disease, which has been known to mankind for over 2000 years. It requires careful monitoring and control. Currently, diabetes ranks fourth worldwide among the NCDs (cardiovascular diseases, cancers, chronic respiratory diseases and diabetes) with prevalence rates of 30%, 13%, 7% and 2%, respectively WHO [50]. It has been projected that by 2020 -2025, the number of people in the developing world with diabetes will increase by more than 2.5 fold; from 84 million in 1995 to 228 million in 2025 [7] and that 70% of deaths due to type 2 diabetes will occur in developing countries. Diabetes mellitus is increasingly being recognized as a major public health problem in developing countries.

Aetiological classification of diabetes mellitus includes type I diabetes (immune-mediated and idiopathic), type 2 diabetes, gestational diabetes and other specific types [48, 49]. However, types 1 and 2 diabetes mellitus appeared to have gained much more popularity among researchers and have generally been considered as the two major categories. In Africa, type 2 diabetes is the predominant form of diabetes in sub-Saharan Africa, accounting for over 90% of cases. The IDF Atlas [51] estimated that 10.8 million people have type 2 diabetes in sub-Saharan Africa in 2006 and this would rise to 18.7 million by 2025, an increase of 80%, as such exceeding the predicted worldwide increase of 55% [52]. In the past, the estimates on mortality of diabetes as the leading cause of death for sub-Saharan Africa were amongst the lowest for all regions globally [53]. This was attributed to Africa's rich biodiversity and high consumption of natural foods, which are rich in complex carbohydrates, proteins and dietary fibre.

There is enormous and escalating economic and social cost of treating type 2 diabetes. Sifelani [54] observed that the number of people seeking medical assistance for diabetes is rising in Africa at a time when health experts reported the continent's overburdened health systems are ill equipped to diagnose the disease. Majority of the poor cannot afford the cost of treatment. Cost of treating diabetes accounts for about 10% of the national income of most countries in Sub-Saahara Africa. National surveys in most parts of Africa indicate that diabetes cases are on the rise due to rapid urbanization as well as fast changing diets which are displacing the traditional ones in favour of the western diets [55]. This makes a compelling case for attempts to reduce the risk of developing diabetes.

Nigeria is among the top 5 countries that have the highest number of people affected by type 2-diabetes in sub-Saharan Africa. Nigeria has about 1.2 million people; South Africa, 841,000; the Democratic Republic of Congo, 552,000; Ethiopia, 550,000 and Tanzania, 380,000 living with diabetes. A national survey had an average prevalence rate of 2.7% with similar pattern in both sexes. There are slightly varying prevalence rates in different geographical locations [12]. Some sporadic figures on prevalence rates of diabetes in Nigeria were published. Cooper et al. [56] studied rural areas in Nigeria and found the prevalence of diabetics to be 2.8%. Wokoma [57] reported that the prevalence of diabetes in Nigeria ranges from 1% to 6%. International Diabetes Federation (IDF) [13] and [51] reported 2.2% and 3.9%, respectively, for type 2 diabetes in Nigeria. The annual increase was 0.3% in prevalence rate. A good number of people still live with it undiagnosed. The prevailing trend to replace the consumption of more complex forms of traditional diets with high intake of refined carbohydrates (Western) diets, in Nigeria, calls for great concern and urgent action. This is because carbohydrate (CHO) foods form over 70% of the local diets. The bleak account of national prevalence poses great challenges to individuals and the nation. Diabetes mellitus is a significant contribution to medical morbidity and mortality risk worldwide. Many factors are involved in its aetiology. The general risk factors include age, obesity, physical inactivity and family history/ previous history of gestational diabetes and poor eating habits. This is because intakes of good sources of dietary fibre such as fruits, vegetables, whole and high fibre grain products and legumes are low due to changes in dietary habit (nutrition transition) across the globe [58]. The main diabetes related risk factors include hyperglycaemia, hyperinsulinaemia/insulin resistance and microalbuminuria/proteinuria [59].

5. An overview of pathogenesis of type 2 diabetes mellitus

Several pathogenic processes are involved in the development of diabetes. Type 2 diabetes is characterized by excessive hepatic glucose production, reduced insulin action and insulin resistance. These alter the utilization of endogenously produced insulin at the target cells. These precipitate hyperglycaemia [60]. The pathogenesis of type 2 diabetes rests on the relationship between carbohydrate metabolism and insulin action. Consumed complex carbohydrates are metabolized to their monosaccharide constituents (glucose, galactose and fructose) in the gut. These monosaccharides have roles in nutrition. Glucose metabolism and absorption receive more attention in relation to diabetes. Glucose, absorbed into the blood

stream, elevates blood glucose level. This rise in blood glucose stimulates the secretion of insulin from the beta-cells of the pancreas to regulate blood sugar levels by increasing active transport of glucose into fat and muscle cells. Post-prandially, blood glucose is absorbed and transported via the portal vein to the liver. The liver maintains blood glucose levels by converting glucose into glucose-6-phosphate and glycogen (glucogenesis). The increased insulin secretion from the pancreas and subsequent cellular utilization of glucose lowers blood glucose levels. Lower blood glucose level decreases insulin secretion. In diseased condition, insulin production is decreased to inhibit glucose uptake into the cells, which precipitates hyperglycaemia. The insulin secreted by the pancreas at this time is not used by the target cells. Hyperglycaemia is a common effect of uncontrolled diabetes and overtime, it causes serious damage to many body systems, particularly, the blood vessels and nerves. Common symptoms include glucosuria, frequent urination (polyuria), excessive thirst (polydypsia), excessive hunger (polyphagia), sudden weight loss, extreme tiredness and blurred vision.

Decreased amount of insulin in circulation decreases lipogenesis and increases lipolysis. Increased lipolysis releases fatty acids from adipose tissues. Fatty acids are also absorbed from the intestinal tract. The rapid release of fatty acids in the blood leads to hyperlipidaemia. The blood level of cholesterol increases, causing the development of atherosclerosis to occur at an earlier age than in non-diabetics and is more pronounced [61]. Elevated circulating levels of free fatty acids derived from adipocytes are the most likely link between insulin resistance and type 2 diabetes [60]. They contribute to insulin resistance by inhibiting glucose uptake, glycogen synthesis and glycolysis, and increasing hepatic glucose production. This leads to a decrease in intracellular concentration of glucose by a reduction in glucose-6-phosphate levels, implicating the glucose transport system as the rate-controlling step for free fatty acid-induced insulin resistance [62].

Free radicals and enhanced oxidative stress with reduced blood levels of anti-oxidants were implicated in the pathogenesis of diabetes and more importantly, in the development of diabetic complications [60, 63]. Free radicals are highly reactive molecules (charged superoxide, hydroxyl radical and nitric oxide). The uncharged hydrogen peroxide species is capable of damaging cellular molecules, DNA, proteins and lipids. These produce altered cellular functions. Oxidative stress is a serious imbalance between the production of free radicals and antioxidant defences. This causes potential tissue damage [64]. Antioxidants play protective role against the effects of hyperglycaemia and free fatty acids *in vitro*. They neutralize free radicals effects in experimentally-induced diabetes in animal models [60] and reduce the severity of diabetic complications [63].

6. Dietary approaches to the management of type 2 diabetes mellitus

A diet is a combination of foods individuals or community habitually eat to exist or live, or use for therapeutic purposes. Diet is known for many years to play a key role as a risk factor for chronic diseases [7]. Conventionally, type 2 diabetes is controlled with diet alone or diet and hypoglycaemic drugs (in combination with insulin in few cases where pancreas produces

no insulin because of age). Objectives of dietary management of diabetes are to: achieve optimal blood glucose and blood lipid concentrations; provide appropriate energy for reasonable weight, prevent, delay and treat diabetes-related complications and improve health through optimal nutrition [65]. The general practice is to counsel people with diabetes on moderation of their food intake through proper food selection with incorporation of low GI foods that contain slowly digestible carbohydrates and increased consumption of dietary fibre-rich foods in combination with increased physical activity. Most often, diabetics are misinformed and advised to consume only those foods with low GI values. The restriction has two adverse effects: either the diabetics become too rigid with their food selection which might cause starvation and frequent hypoglycaemic attacks [66] or consume more carbohydrate per meal from the low GI diets. These precipitate poor diabetic control (hyperglycaemia). This has resulted in reduced intake or total avoidance of starchy staples and overall poor diabetes management in Nigeria with its attendant high cost of medical treatment. The types of foods/diets eaten in Nigeria vary tremendously and depend on several factors. Climate, environment, cost and availability of foods, and religious beliefs are among the factors. There are also significant differences in eating habits between the rural and urban populations. The latter increasingly adapt to western food habits [67]. The promotion of indigenous mixed diets still remains a powerful weapon in the fight against diabetes.

7. Dietary recommendations for type 2 diabetes mellitus

Nutrients are needed in certain amounts for good health. The type of food/diet people eat, in all their cultural variety, is a key universal factor that defines and affects people's health, growth and development. However, due to some environmental, genetic, physiological and metabolic factors, humans become susceptible to conditions that influence the body's homeostasis, nutrient intake and metabolism. To meet the challenges of optimizing nutrient utilization for specific conditions, dietary recommendations are made for various diet-related diseases. These are based on the causal factors and aim of dietary intervention in a particular disease condition. These involve consideration for the key nutrients in metabolic functions, their daily required amounts with reference to age and sex, their food sources and individual quantities of selected foods. These foods must offer desirable short or long-term health benefits without adverse effects. Dietary recommendations for prevention of diet-related chronic diseases and for people with diabetes were published by WHO [7] and American Diabetes Association [15], respectively. One major emphasis in these recommendations is that these diets should be close to normal (family) diet. In diabetes mellitus, the three energy-giving nutrients are involved. Based on this, adequate supply and intake of carbohydrate, protein and fat as well as micronutrients (vitamins and minerals) becomes an important factor to consider in diet and glycaemic control. The diet should contain 50-60% carbohydrate, 30-35% and 10-15% protein relative to the individual's total daily caloric allowance. Fruits, vegetables and spices are rich in bioactive constituents [68, 69]. Bioactive constituents (dietary fibre, phytochemicals and anti-oxidants) of plant foods are receiving attention with regard to their roles in diabetes management. Most studies used different fibre sources (legumes, cereals and

leaves) at different levels of incorporation [5-15%) into single meals of subjects [70, 71, 72, 73]. These studies tend to support the American Diabetes Association (ADA) position [15] that the public should consume adequate amounts of dietary fibre from a variety of plant foods. Unfortunately, recommended dietary fibre intakes 20-35g per day for healthy adults and the aged [7], and 5g per day for children [74], respectively, are not being met. Recent studies have shown that high carbohydrate, high fibre diets have low glycaemic index and reduce blood cholesterol and triglyceride levels. This more flexible glycaemic index concept replaces the therapeutic distinction between simple versus complex carbohydrates. Quantification of bioactive compounds *in vivo* is costly and time consuming. Liu [75] reported that synergistic effects of phytochemicals in fruits and vegetables are best acquired through whole-food consumption, not from expensive dietary supplements. It is recommended that consumers should eat 400g or 5 servings of fruits and vegetables from a wide variety of fruits and vegetables/day.

One limitation of dietary recommendations is the problem of translating them into practical terms. This appears to be a major gap in knowledge, which should be explored to translate the accumulated scientific evidence of plant foods benefits into practical terms. FAO/WHO/UNU [76] recommended the food-based dietary guideline (FBDG) to address problem of dietary inadequacies and poor nutrient intake. This ensures supply of nutrients per 1000kcal (nutrient density) of the traditional diet as consumed relative to standard values. The concept is used to express required, desirable nutrient intake and population goals relative to energy intake. It strongly emphasizes that food-based approaches are the only sustainable strategy to improve the nutritional status of all. Its major advantages are - it is easy to adopt and imple‐ ment; emphasizes changes that promote adequate vitamins and minerals, and reduce risks of food-borne illness, obesity, diabetes, cancers and CVD. It also portrays long term effects of diets as consumed [76]. For instance, a total of 15-20g dietary fibre/1000kcal and sodium 1000mg/1000kcal are recommended. McCarty [33] proposed a dietary 'phytochemical index' as a means of improving phytochemical nutrition of clients/patients. This index is the per‐ centage of dietary calories derived from foods rich in phytochemicals. Calories derived from fruits, vegetables, legumes, whole grains, nuts, seeds, fruit/vegetable juices, soy products, wine, beer and cider- and foods compounded therefrom, would be counted in this index.

Harden et al. [77] advocated direct evaluation of GI of many meal combinations based on indigenous, more widely and frequently consumed foods. Two principal approaches were used to study the effects of increasing carbohydrate and fibre in diabetes management:

i. supplementation of the low fibre foods with fibre-rich sources (for instance, guar gum, flours from tallow tree, counter wood tree seeds and locust bean); and

ii. selective use of dietary fibre–rich foods.

Selective and holistic use of dietary fibre content of a mixed meal than the soluble non-starch polysaccharides (NSP) supplements has currently become of research interest. It is because the supplementation approach compromises sensory properties of indigenous food products with anti-diabetic potentials at clinically effective and acceptable levels [78]. Translation of the nutrient recommendations for specific conditions into foods for easy culinary application and

appropriate nutrient intake is an integral part towards achieving the goals of dietary recommendations.

8. Problems associated with use of medicinal plants/traditional medicine and diabetes control

WHO reported that in several countries and areas, about 80% of the third world countries and 40-60% of total world population use traditional medicine instead of orthodox medicine for health-care. The process of extraction and purification of plant extracts affect the unit cost [3]. These expensive products are unaffordable for the low income countries. The low demand for drugs led to the use of medicinal plants as herbal components of health foods and for preventive medicine. This new expanding market gave rise to nutraceuticals (nutriceuticals). Culhane [5] reported nutraceuticals as "foods derived from a naturally occurring substance (in pills or powder or other medicinal forms), which can and should be consumed as part of the daily diet, and serves to regulate or otherwise affect a particular body process when ingested". These foods are known as medicinal foods, phytofoods, phytonutrients and functional foods. All of these terms meant substances that may or may not be considered as foods or parts of food but provide health benefits when eaten. However, more people prefer traditional medicine. This is because it provides holistic treatment (treatment that caters for the spirit, body and soul). The need for traditional medicine arose from the indigenous knowledge. This showed that aetiology of diseases does not only come from physiological imbalance and psychological causes as in orthodox medicine, but can come from spiritual causes, astral influence, esoteric causes and imbalance in cosmic natural forces. This could be associated with the belief by some diabetic patients that their condition is diabolical (personal communication). Every region has had, at one time or the other in its history, a form of traditional medicine. However, distinction exists between the use of traditional medicine and traditional plant foods as regards therapeutic agents used in diabetes management and health promotion. The misconception in the use of these indigenous medicinal plants precipitated self-medication when such plants are used. This poses serious problem in diabetes control in Nigeria. Consumers take medicinal plants, herbal products and nutraceuticals as food and think they are safe at any dose. Concerns raised about the interaction between herbal preparation and drugs are that herbal remedies might – i) increase the effect of an antidiabetic drug and plunge blood sugar to dangerously low level; ii) decrease the effect of blood pressure medication and cause high blood pressure and stroke; iii) decrease the effect of an anti-infection agent, letting the infection get out of control; iv) increase or decrease the effect of a blood thinner such as warfarin and cause either bleeding episode or formation of a dangerous clot. The combination of orthodox and traditional medicines has negative impact on people with diabetes in Nigeria. This may explain high incidence of cases of uncontrolled diabetes and associated complications in patients admitted in hospitals in Nigeria. The major link between the use of traditional medicine and traditional plant foods is that their uses are community-based and indigenous. Each community has its own peculiar approach to health and diseases even at the level of ethno-

pathological perception of diseases and therapeutic behaviours. This gives indigenous knowledge in agriculture, medicine and health its diverse and pluralistic nature. The implication is that success for use of any indigenous plant foods that possess antidiabetic potential when incorporated into the family diets, could offer sustainable health benefits to the community/consumers of such plant foods.

9. Bioactive constituents and their effects on diabetes

Several terms have been used to describe the therapeutic potentials of plants. Health-promoting activities, bioactive constituents, medicinal properties (often used in orthodox and traditional medicine), natural plant products and biological response modifiers are examples of such terms. All plants, especially the wild ones, are potential sources of biological active molecules. These compounds protect plants against predators and other damage but are not directly essential for growth. They are known as secondary chemical compounds or metabolites. The plant constituents useful extractable substances in their storage organs (leaves and seeds/roots) in quantities sufficient to be economically useful as raw materials for various scientific technological and commercial applications [3].

Some plant constituents appear to be disease specific. The plants for consideration when a hypoglycaemic property of a plant is elucidated were reported. Ivorra et al. [28] studied different compounds isolated from plants with attributable hypoglycaemic activity. They gave a broad classification as follows: polysaccharides and proteins; steroids and terpenoids; alkaloids; flavonoids and related compounds. Drewnowski and Gomez-Carneros [29] and Noor et al [23] reported phenols and polyphenols, flavonoids, isoflavones, terpenes and glucosinolates in vegetables and fruits; Thompson et al. [79] included phytate in bean flour, which reduced GI. Iwu et al. [80] found alkaloids in yam. Several studies have published similar effects with dietary fibre (non-starch polysaccharides, NSPs) [31, 73]. A new classification of dietary fibre (water-soluble and insoluble dietary fibre) was based on their solubility characteristics [81]. The soluble dietary fibre is highly viscous and has added viscosity as functional property in the evaluation food/diets. These NSPs lower blood glucose level by impeding glucose absorption from the gastrointestinal tract and reduce post-prandial hyperglycaemia. The water-insoluble NSP are mainly obtained from structural carbohydrates (cellulose and lignin of cell walls) of starchy roots/tubers and cereals. The water-soluble NSP are obtained from storage carbohydrates (gum and hemicellulose) of legumes and as pectin from fruits and vegetables. The phytochemicals are basically sourced from fruits and vegetables.

Widely used parameters for clinical studies in diabetes are post-prandial blood glucose, glycaemic index (GI) and glycaemic load (GL). Jenkins et al. [82] introduced the concept of GI to classify both single foods and mixed meals on the basis of their potential for increasing the blood glucose concentration. The starchy foods have high GI (>70%) compared to the low values (<50%) for vegetables, fruits, legumes. The GL is defined as the product of the amount

of available carbohydrate in a certain amount of food and its GI divided by 100 [83]. Low GI-based diets tend to maintain glucose and insulin at a moderate level avoiding the hyperglycaemic state [84]. This is based on advantages of the GI concept: i) GI and GL are determined both on single and mixed meals; ii) they permit proper selection and combination of low and high GI foods to achieve good glycaemic control and prevent hyperglycaemia; iii) they prevent fear of excessive intake of low or high GI foods and resultant hypoglycaemia/hyperglycaemia; and iv) hyperinsulinaemia is abated when both GI and GL are considered in dietary counselling. The link between GI and GL simply means that although both GI and GL elicit information on carbohydrate content of foods in relation to their blood glucose response. GI is associated with the quality of carbohydrate in a food/meal while GL relates to the overall quantity of carbohydrate in the same food/meal [85]. However, when these low GI (low GL) foods are habitually consumed in large amounts, high glycaemic effect may manifest over time. Based on this, attention is drawn to researchers on the limitation of the use of glycaemic index values alone in diabetes management. The practical application of the Gl, used in combination with other information on food composition, is promising in guiding good food choices, especially for people with diabetes. Englyst et al. [87] proposed the inclusion of rapidly digested starch (RDS) and slowly digested starch (SDS) to account for limitations of GI. More recently, resistant starch (RS) has received attention as one of the components of carbohydrate foods that are closely linked to glycaemic control [86]. Salijata *et al.* [34] observed that the justification of similarity of RS with NSP is that RS assays as insoluble fibre and has the physiological benefits of soluble fibre. They reviewed the importance of high amylose content and high amylose:amylopectin ratio in foods/diets in the post-pandrial glycaemic and insulinaemic responses. A higher amylose lowers digestibility of starch due to positive correlation between amylose level and formation of RS [88]. Plants with these hypoglycaemic activities collectively exert their effects in two major ways. They either improve insulin sensitivity to glucose at the peripheral cells to increase glucose uptake and reduce hyperglycaemia. Or, they act on insulin production-related actions to improve insulin production and control of blood sugar homeostasis.

Evans et al. [60] has reported that pathogenesis of diabetes is better appreciated and should be discussed in line with hyperglycaemia and elevated free fatty acid in the blood in relation to oxidative stress and production of free radicals. Some plants with hypolipidaemic activities were included by several authors as those that may assist in diabetes control. This is because diabetes and cardiovascular disease are closely related. The active ingredients identified *in vivo* for this purpose are antioxidants (vitamin A, beta-carotene, vitamin E and tannins) [89, 90]. The degree of these constituents in foods and their relative importance varies with the chemical compound, specie, part and age of the plant as well as environment. From the above perspective, the following operational definition will be used for documenting the antidiabetic potential/effects of identified plant foods. *Anti-diabetic plant foods/diets* are those plant foods/diets that contain any of the chemical compounds, shown to reduce hyperglycaemia or induce hypoglycaemia through their effect on the improvement of insulin resistance or insulin supply to the peripheral cells.

10. Documentation of anti-diabetic potentials of selected Nigerian indigenous plant foods

The 1978 Alma Ata declared that traditional medicine is the surest means to achieve total health care coverage of the world's population. This has encouraged the use of medicinal plants. Currently, the active ingredients in most plants with anti-diabetic potentials are elucidated pharmacologically. Consequently, it was a bit difficult to identify edible Nigerian indigenous plants from huge database on medicinal plants. Information on their constituents of nutritional importance was lacking. Invariably, not all traditional medicinal plants qualify as plant foods. Bosch et al. [91] as cited in Ogbu et al. [92] reported that the total number of species of edible plants in primary use in Africa is 1004. However, a little above 50% of the number of medicinal plants was reported as 1975. In Nigeria, Federal Environmental Protection Agency (FEPA) shows that 20 species of the plants were in extinction since 1950. Another 431 species are endangered, 45 species are classified as rare, 20 species are vulnerable and 305 species are endemic [93]. Not all plants with antidiabetic potentials published online may be available or edible in Nigeria. The local herbalists keep secret the information on health benefits of indigenous crops to enhance their patronage. Preliminary identification of the anti-diabetic potentials of these plant foods becomes necessary to improve their food diversification and consumption.

11. Sequence for literature review

Surveys on traditional food systems are commonly used to document information on indigenous foods with health-benefits [94]. Google search was used to review literature on published works on ethnobotanical surveys in northern and southern regions of Nigeria. These were used to identify commonly consumed indigenous plants. Some related unpublished works were also used to supplement published data. Information obtained include botanical names of the plant foods where available, habitat (cultivated (C), wild (W) or semi-wild (S)), part used, culinary uses, anti-diabetic potentials/effects of single foods and diets and corresponding references. From the profile of edible indigenous plant foods, those that have antdiabetic potentials were selected based on their bioactive constituents, proven to be active ingredients in attenuating post-prandial blood glucose. Additional information on anti-diabetic effects of some of the plant foods/diets evidenced by *in vivo* or *in vitro* studies were also elucidated.

12. Results

The concept of food groups of plant origin was used to present the results on documentation of Nigerian indigenous plant foods and those with anti-diabetic potentials. This was to encourage increased diversification and culinary uses. These food groups include fruits, vegetables, spices and condiments, grain legumes, nuts and oil seeds as well as starchy roots/

tubers/fruits and cereals. Forty-eight families of plant foods were identified. Out of 241 plant species (spp) identified, 80 fruits, 77 vegetables, 68 spices and condiments, 22 grain legumes/ nuts/oil seeds and 19 starchy roots/tubers/fruits and cereals were documented. Twelve out of 22 grain legumes/nuts/oil seeds and 11 out of 19 roots/tubers/cereals were soup thickeners. Only 3 spp of fruits, 16 spp of vegetables, 27 spp of spices/condiments/grain legumes and 10 spp of starchy staples have anti-diabetic potentials *in vivo or in vitro* (Table 1]. Twenty-five indigenous diets as consumed had anti-diabetic effects (Tables 2]. Three of the *Candida tropicalis* fermented low GI starchy staple (cassava/maize/sorghum) flours were used to formulate high dietary fibre diets using food-based approach of 10% protein and 20g total dietary fibre/1000kcal in a 1:2 ratio of soluble: insoluble dietary fibre. The diets were composed of fermented cassava/maize/sorghum flours (commonly used to prepare thick paste tradition-ally known as "foofoo". They are eaten with traditional soup blended with *Cola gigantea* flour (a soup thickener) and other standard ingredients for rat bioassay to mimick traditional diets as consumed. These diets reduced post-prandial blood glucose concentrations of the diabetes-induced adult rats. More of the most commonly consumed vegetables than fruits were cultivated. The indigenous diets that had anti-diabetic effects did not contain any fruit group in their various recipes. They contained vegetables as part of the ingredients. This observation supports the report by Ene-Obong et al. [39]. It showed that fruit consumption was conspicu-ously absent in a survey of commonly consumed foods in all the 6 geo-political zones in Nigeria. The implication is that fruit intake as source of anti-oxidants and phytochemicals in Nigeria is disturbingly low and needs urgent intervention strategies. The low percentage of plants with proven anti-diabetic potentials underscores the need to explore anti-diabetic potentials of Nigerian rich biodiversity towards diversification of their utilization to optimize their health benefits. One significant observation (Table 2] is that apart from the *Afzelia*-cowpea pudding, all the diets investigated by various authors were based on starchy staples. These foods have high nutrient density and are consumed frequently and appreciably. They serve as desirable vehicles to improve utilization and consumption of phytochemical – and anti-oxidant–rich indigenous foods for improved diabetes control and prevention. However, the limitation of the work is that the identified diets were mostly reports from diets consumed in Southern Nigeria. There are wide variations in recipes used for the same traditional diets in many ethnic groups in Nigeria. The diets in this study may serve more or less as preliminary and/or available research work rather than representative of all Nigerian traditional diets. Another limitation is the differences in their concept and determination of "50g of digestible carbohydrate" of reference and experimental foods/diets. Some studies correctly determined the digestible carbohydrate contents of the food samples used, and some simply obtained the carbohydrate content by difference (proximate analysis). These discrepancies in the analytical methods pose some problems in the use of such available data. It calls for further clinical evidence-based studies to authenticate these claims for proper application in culinary practices and optimization of their health benefits.

Family name	Botanical name	C/W/S	Part studied and form in which the food was prepared for assay	Type of assay (AM = animal model)	Potential active ingredients	Anti-diabetic property	References
FRUITS							
Oleaceae	*Carica papaya*	W	Fruit	*In vivo*	Dietary fibre	Not determined	[95]
Myrtaceae	*Psidium guajava Linn.*	C	Fruit and fruit juice	*In vivo* (humans)			[96, 97]
Chrysobalanaceae	*Parinari curatollifolia*	W	Fresh fruit, paste		High viscosity	Not determined	[98]
VEGETABLES							
Bombacaceae	*Adansonia digitata*	W	Leaves extract	*In vivo*	Mucilage	Anti-hyperglycaemic	[99]
Cucurbitaceae	*Citrulus lanatus*	C	Seeds flour	*In vitro*	Dietary fibre	Not determined	[100]
Cucurbitaceae	*Telfairia occidentalis*	C	Ground leaves pulp	*In vitro; In vivo* (AM)	High phytochemical constituents (alkaloids, tannins, flavonoids, steroids, anthacyanin, carotenoides)	Antioxidant; anti-hyperglycaemic	[101, 102]
Cucurbitaceae	*Momordica charantia*	S	Fruit extract	*In vivo*	Phytochemicals	Anti-oxidant, anti-hyperglycaemic	[45, 24]
	Vernonia amygdalina	C	Ground leaf pulp	In vitro	High phytochemical constituents (alkaloids, tannins, flavonoids, steroids, anthacyanin, carotenoides)	Hypoglycaemic	[102, 103]
Labiatae	*Occimum gratissimum*	S	Ground leaf pulp	*In vitro*	The same constituents	Not determined	[102]
	Gnetum africana	S	Ground leaf pulp	*In vitro*	The same constituents	Not determined	[102]
Tiliaceae	*Corchorus olitorus*	W	Ground leaf pulp	*In vitro*	The same constituents	Not determined	[102]

Family name	Botanical name	C/W/S	Part studied and form in which the food was prepared for assay	Type of assay (AM = animal model)	Potential active ingredients	Anti-diabetic property	References
Fabaceae	*Pterocarpus santalinoides*	W	Ground leaf pulp	*In vitro*	The same constituents	Not determined	[102]
	Pterocarpus mildbreadii	S	Ground leaf pulp	*In vitro*	The same constituents	Not determined	[102]
	Abelmoschus esculentus	W	Pod	*In vivo* (animal model)	Mucilage, dietary fibre	Antioxidant anti-hyperglycaemic	[99, 104, 105, 106]
	Solanium melongena	C	fruit	*In vitro*	Phytochemical (anthocyanin)	Anti-oxidant	[45]
	Solanum tuberosum	C	Stem	*In vitro*	Resistant starch	Anti-hyperglycaemic	[45]
	Moringa olifera	S	Leaves and seeds extracts	*In vivo* in human & AM	Phytochemicals	Anti-hyperglycaemia; anti-lipidaemia	[107]
SPICES AND CONDIMENTS/ GRAIN LEGUMES, NUTS, OIL SEEDS							
Alliaceae	*Allium cepa var. aggregatum*	W	Dried bulb powder	*In vivo* (human & AM)	Anthocyanins	Anti-hyperglycaemia	[24, 47]
Alliaceae	*Allium sativa*	C	Bulb extract	*In vivo* (human/AM)	Anthocyanins (allicin)	Anti-hyperglycaemia	[47]
Euphorbiaceae	*Ricinus communis*	C	Seeds extract	*In vivo* (AM)	Not determined	Anti-hyperglycaemia	[108]
	Gongronema latifolium	C	Ground leaves pulp		High phytochemical constituents (alkaloids, tannins, flavonoids, steroids, anthacyanin, carotenoides)	Not determined	[102]
	Murraya koenigii	W	Leaves extract	*In vivo* (AM)	Not determined	Hypoglycaemic	[24, 47]

Family name	Botanical name	C/W/S	Part studied and form in which the food was prepared for assay	Type of assay (AM = animal model)	Potential active ingredients	Anti-diabetic property	References
	Zingiber officinale	W	Fresh or dried rhizome powder	*In vivo*	Not determined	Antihyperglycaemia	[24, 47]
	Piper nigrum	C	Fruit extract	*In vitro*	Flavonoids	Anti-oxidant	[45]
Piperaceae	*Piper guineense*	W	Fruit extract	*In vitro*	Flavonoids	Anti-oxidant	[45]
Vitaceae	*Cissus pulponea syn. rotundofolia*	W	Stem flour	*In vivo* (AM)	High viscosity, dietary fibre	Hypoglycaemic	[70]
Basidiomycetes	*Pleurotus tuberegium*	C	Sclerotium flour	*In vitro*	Dietary fibre	Not determined	[42]
Caesalpiniaceae	*Afzelia Africana*	W	Seeds flour	*In vitro*	Dietary fibre	Hypoglycaemic	[42, 73]
Caesalpiniaceae	*Brachystegia nigerica* Hoyle ex A. P. D. Jones	W	Seeds flour	*In vitro*	Dietary fibre	Not determined	[42]
Caesalpiniaceae	*Detarium microcarpum*	W	Seeds flour	*In vitro*	Dietary fibre	Hypoglycaemic	[42, 73]
Fabaceae	*Mucuna pruriens* (L.) D. C. var. utilis	C	Seeds flour	*In vitro*	Dietary fibre	Not determined	[42]
Fabaceae	*Mucuna sloanei* Fawcett	C	Seeds flour	*In vitro*	Dietary fibre	Not determined	[42]
Fabaceae	*Vigna unguiculata* (L.) Walp var. unguiculata	C	Seeds flour	*In vivo*	Dietary fibre	Antihyperglycaemic, anti-hyperlipidaemic	[106, 109]
Fabaceae	*Vigna unguiculata*	C	Seeds flour	*In vivo*	Not determined	Antihyperglycaemia, anti-hyperlipidaemia	[109]

Family name	Botanical name	C/W/S	Part studied and form in which the food was prepared for assay	Type of assay (AM = animal model)	Potential active ingredients	Anti-diabetic property	References
	(L.) Walp var. *dekindtiana*						
Fabaceae	*Arachis hypogea* (L.)	C	Seeds flour	*In vitro*	Mucilage	Not determined	[38]
Fabaceae	*Glycine max.* (L.)	C	Seeds flour	*In vitro*	Dietary fibre	Not determined	[110]
Irvingiaceae	*Irvingia gabonensis*	C	Seeds flour	*In vitro*	Soluble dietary fibre	Anti hypoglycaemic	[106, 111]
Irvingiaceae	*Irvingia wombulu*	S	Seeds flour	*In vitro*	Soluble dietary fibre	Anti-hypoglycaemic	[106, 111]
Lauraceae	*Bielschmedia gabonensis* (Meisn) Benth. ex Hook. f.	W	Seeds flour	*In vitro*	High viscosity, dietary fibre, low GI	Not determined	[112]
Papilionaceae	*Sphenostylis sternocarpa* (a. Rich.) Harms	C	Seeds flour	*In vitro*	Dietary fibre	Antihyperglycaemia, anti-hyperlipidaemic	[109]
Papilionaceae	*Vigna subterranean* (L.) Verdc.	C	Seeds flour	*In vitro*	Dietary fibre	Antihyperglycaemia, anti-hyperlipidaemic	[106, 109]
Papilionaceae	*Cajanus cajan* (L.) Millip.	C	Seeds flour	*In vivo*	Dietary fibre	Anti-hyperglycaemic	[42]
Sterculiaceae	*Cola gigantea*	W	Seeds flour	*In vitro*	High viscosity, dietary fibre, low GI	Not determined	[112]
Sterculiaceae	*Garcina cola*	C	Nuts		Not determined	Anti-oxidant, hypoglycaemic	[113, 114, 24]
STARCHY/ROOTS/TUBERS/FINGERS & CEREALS							
Dioscoreaceae	*Dioscorea documentum*	C	Tubers extract	*In vivo* (AM)	Alkaloids	Hypoglycaemic	[24]
Dioscoreaceae	*Dioscorea alata*	C	Tuber flour	*In vitro*	Dietary fibre	Not determined	[115]

Family name	Botanical name	C/W/S	Part studied and form in which the food was prepared for assay	Type of assay (AM = animal model)	Potential active ingredients	Anti-diabetic property	References
			Seeds flour	*In vitro*	Dietary fibre	Anti-hyperglycaemia	[116, 117, 118]
Poaceae	*Oryza sativa*	C	Seeds flour	*In vivo*	Dietary fibre, polyphenols and phytic acid	Anti-hyperglycaemic	[119]
Poaceae	*Zea mays*	C	Seeds, *Candida tropicalis* fermented flour	*In vitro*	Dietary fibre, low GI	Not determined	[120]
Poaceae	*Sorghum bicolor*	C	Seeds, *Candida tropicalis* fermented flour	*In vitro*	Dietary fibre, low GI	Not determined	[120]
Euphorbiaceae	*Manihot esculenta*	C	Roots, *Candida tropicalis* fermented flour	*In vitro*	Dietary fibre, low GI	Not determined	[120]
	Ipomea batatas	C	Leaf and stem extracts; stem	*In vivo* (AM)	Flavones ; dietary fibre	Anti-oxidant, hypoglycaemia;	[24, 121]
Musaceae	*Musa paradisica*	C	Unripe fruit flour	*In vivo* (animal model)	Saponins, flavonoids, tannins & alkaloids	Anti-oxidant, hypoglycaemia	[89]
	Abrus precatorius		Seeds flour	*In vivo* (AM)	Not determined	Hypoglycaemic	[24, 114]

C = Cultivated; W = Wild; Semi-wild = S

Table 1. List of identified Nigerian indigenous plant foods (single foods) with anti-diabetic potentials/effects by food groups

Name of local diet as consumed/ snacks/drinks	Description of diet	Type of assay AM= animal model	Potential active ingredients	Anti-diabetic property	Ref.
Detarium macrocarpum soup meal	Traditional soup prepared with *Detarium* seed flour, meat, fish, red palm oil, salt, spinach, fresh tomatoes, waterand consumed with boiled *Oryza sativa* seeds	*In vivo* (humans)	Dietary fibre	Hypoglycaemic	[122]
Detarium bread meal	Breadrolls prepared with *Detarium* seed flour and other basic bread ingredients (hydrogenated fat, improver, fresh yeast, water)	*In vivo* (humans)	Dietary fibre	Anti-hyperglycaemic	[123]
Sphenostylis sternocarpa gruel	Gruelprepared with *Sphenostylis* seed flour and water to produce a gruel	*In vivo* (humans)	Dietary fibre	Anti-Hyperglycaemic	[124]
Afzelia-cowpea moi-moi	Moi-moi (*V. unguiculata* seed pudding) prepared with *Afzelia* seed flour	*In vivo* (humans)	Dietary fibre	Anti-Hyperglycaemic	[72]
Gari with *afang* soup	Gari *with Gnetum africanum* leaf-based traditional soup prepared with modified recipe by Ana (125)	*In vivo* (AM)	Not determined	Anti-Hyperglycaemic	[126]
Pounded yam with *edikang ikong* soup	*Talinum triangulare* and *Telfairia occidentali*s leaves-based traditional soup prepared with modified recipe by Ana (125) and consumed with boiled yam (*Dioscorea rotundata*) tuber pounded into a thick dough	*In vivo* (AM)	Not determined	Anti-Hyperglycaemic	[126]
Ekpang nkukwo	Cocoayam *(Colocasia esculentum) corm* /wateryam (*Dioscorea alata*) tuber pudding prepared with modified recipe by Ana (125)	*In vivo* (AM)	Not determined	Anti-Hyperglycaemic	[126]
Plantain porridge with beans	*Musa paradisiaca* fruit cooked with *V. unguiculata* to produce a savoury dish with modified recipe Ana (125)	*In vivo* (AM)	Not determined	Anti-Hyperglycaemic	[126]
Afzelia-plantain based biscuits	*Afzelia* seed and plantain (*Musa paradisiaca*) finger flours prepared with other basic biscuit ingredients (baking fat, salt and water without sugar)	*In vivo* (humans)	Dietary fibre	Anti-Hyperglycaemic	[71]
Yam flour with 'ewedu'	Cooked, thick paste made from *Dioscorea rotundata* tuber flour (*amala*) consumed with traditional soup	*In vivo* (humans)	Low GI	Hypoglycaemic	[127]

Name of local diet as consumed/ snacks/drinks	Description of diet	Type of assay AM= animal model	Potential active ingredients	Anti-diabetic property	Ref.
(Corchorus olitorius) soup	prepared with *Corchorus olitorius* leaves, tomato sauce, beef, salt, local spices				
Fermented cassava flour with *'ewedu'* *(Corchorus olitorius)* soup	Cooked, thick paste made from *Manihot esculenta* tuber flour (*lafun*)consumed with traditional soup prepared with *Corchorus olitorius* leaves	*In vivo* (humans)	Low GI	Hypoglycaemic	[127]
Maize flour with *'ewedu'* *(Corchorus olitorius)* soup	Cooked, thick paste made from *Zea mays* flour consumed with raditional soup prepared with *Corchorus olitorius* leaves	*In vivo* (humans)	Low GI	Hypoglycaemic	[127]
Fermented cassava flour with "ogbono soup	Cooked, thick paste made from *Manihot esculenta* flour (*lafun*) consumed with traditional soup prepared with Irvingia spp seeds	*In vivo* (humans)	High viscosity; reduced digestibility	Hypoglycaemic	[128]
Plantain flour with 'ogbono'soup	Cooked, thick paste made from *Musa parasidiaca* flourconsumed with traditional soup prepared with *Irvingia* spp seeds	*In vivo* (humans)	High viscosity; reduced digestibility	Hypoglycaemic	[128]
Fermented cassava flour with "egusi soup'	Cooked, thick paste made from *Manihot esculenta* root flourconsumed with traditional soup prepared with *Colocynthis citrillus* seeds	*In vivo* (humans)	High viscosity; reduced digestibility	Hypoglycaemic	[128]
Plantain flour with 'egusi soup'	Cooked, thick paste made from *Musa parasidiaca* flourconsumed with traditional soup prepared with *Colocynthis citrillus* seeds other ingredients	*In vivo* (humans)	High viscosity; reduced digestibility	Hypoglycaemic	[128]
Fermented cassava flour with pepper soup	Cooked, thick paste made from *Manihot esculenta* root flourconsumed with traditional soup prepared with *piper spp* and other ingredients	*In vivo* (humans)	High viscosity; reduced digestibility	Hypoglycaemic	[128]
Plantain flour with pepper soup	Cooked, thick paste made from *Musa parasidiaca* flourconsumed with traditional soup prepared with *piper spp* and other ingredients	*In vivo* (humans)	High viscosity; reduced digestibility	Hypoglycaemic	[128]

Name of local diet as consumed/ snacks/drinks	Description of diet	Type of assay AM= animal model	Potential active ingredients	Anti-diabetic property	Ref.
Boiled yam with fish stew	Boiled yam (*D. rotundata*) consumed with stew prepared fish, vegetable oil, fresh tomatoes, red pepper and vegetables	*In vivo* (human)	Dietary fibre	Anti-hyperglycaemic; anti-hyperlipidaemic	[129]
Cassava flour with vegetable soup	Cooked, thick paste made from *Manihot esculenta* root flourconsumed with traditional soup prepared with 'soup thickener' fresh vegetables, beef/fish, vegetable oil, fresh tomatoes and red pepper	*In vivo* (human)	Dietary fibre	Anti-hyperglycaemic; anti-hyperlipidaemic	[129]
Yam flour with vegetables stew	Cooked, thick paste made from *D. rotundata tuber* flour consumed with traditional soup prepared with 'soup thickener' fresh vegetables, beef/fish, vegetable oil, fresh tomatoes and red pepper	*In vivo* (human)	Dietary fibre	Anti-hyperglycaemic; anti-hyperlipidaemic	[129]
Boiled beans and boiled plantain with beef/fish stew	Boiled cowpea (*V. unguiculata*) and boiled *Musa parasidiaca* consumed with traditional soup prepared with 'soup thickener' fresh vegetables, beef/fish, vegetable oil, fresh tomatoes and red pepper	*In vivo* (human)	Dietary fibre	Anti-hyperglycaemic; anti-hyperlipidaemic	[129]
Fermented cassava/*C. gigantea* blend	*Candida tropicalis* fermented *Manihot esculenta* root flour blended with *Cola gigantea* seed flour and other basic ingredients for rat study to provide 10% protein and 20g total dietary fibre/ 1000kcal	*In vivo* (AM)	Dietary fibre, protein	Anti-hyperglycaemia	[130]
Fermented maize/ *C. gigantea*	*Candida tropicalis* fermented *Zea mays* seed flour blended with *Cola gigantea* seed flour and other basic ingredients for rat study to provide 10% protein and 20g total dietary fibre/1000kcal	*In vivo* (AM)	Dietary fibre, protein	Anti-hyperglycaemia	[130]
Fermented sorghum/C. gigantea	*Candida tropicalis* fermented *Sorghum bicolor* seed flour blended with *Cola gigantea* seed flour and other basic ingredients for rat study to provide 10%	*In vivo* (AM)	Dietary fibre, protein	Anti-hyperglycaemia	[130]

Name of local diet as consumed/ snacks/drinks	Description of diet	Type of assay AM= animal model	Potential active ingredients	Anti-diabetic property	Ref.
	protein and 20g total dietary fibre/ 1000kcal				
C = Cultivated; W = Wild; Semi-wild = S					

Table 2. List of identified Nigerian indigenous plant-based diets with anti-diabetic effects

13. Conclusions and recommendations

Diet therapy, undisputedly, has long been recognized as key tool in the clinical management of diabetes. The challenge centres on how to translate the existing scientific evidence into practical terms for individual and household application in the management of diabetes mellitus. Relatively, a few clinical studies were published in Nigeria. Widely used parameters for diabetes-related clinical studies in Nigeria are post-prandial blood glucose response, anti-oxidant activity, lipid profiles and GI of diets. Most of the studies conducted on single foods were on dietary fibre. Much more indepth research is needed on phytochemical constituents of the rich national flora as regards phytochemical index and diabetes control. This is because health benefits of these indigenous plants are of public health importance. Based on recent documentation, Nigeria is rich in varieties of plant foods. Only a few varieties or cultivars were captured relative to diverse nature of Nigeria. It has generated a database for future investigations. Relevant research outputs on the plant foods would encourage diversification and increase consumption to maintain dietary adequacy and optimize their health benefits/ therapeutic potentials.

Much of the *in vivo* studies on antidiabetic effects of indigenous diets were conducted on human subjects. Levels of incorporation of fruits and vegetables into the traditional recipes are inadequate. The recipes used for traditional diets vary from one region/ethnic group to another in Nigeria. The variations in recipes for these diets might influence their nutrient concentrations and effects on blood glucose level. It is imperative to fill this gap using FBDG. This guideline proposed by FAO/WHO/UNU [76] has not been embraced and applied widely to enhance their health benefits in communities despite its advantages over the traditional and orthodox medicine. Rat study model to simulate this approach using high dietary fibre plant-based diet showed that traditional mixed diet as consumed can attenuate post-prandial blood glucose concentration in diabetic adult rats. There is research need to focus on wider varieties of traditional diets as consumed in Nigeria.

The goal for optimizing the use of indigenous plants with anti-diabetic potentials to control and prevention type 2-diabetes rests on conducting controlled clinical trials using food-based approach as the last step to establish their efficacy in humans. Evidently, these diets adequate

in macronutrients, micronutrients and phytochemicals can retard and prevent diabetic complications. Optimum utilization of these indigenous anti-diabetic plant foods in Nigeria and their diversification would enhance management of diabetes and improve health of people in the communities.

Author details

Elizabeth A. Udenta[1*], Ikemefuna C. Obizoba[1] and Oluwafemi O. Oguntibeju[2]

*Address all correspondence to: elizabeth.udenta@unn.edu.ng

1 Department of Home Science, Nutrition and Dietetics, Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria

2 Oxidative Stress Research Centre, Department of Biomedical Sciences, Cape Peninsula University of Technology, Bellville, South Africa

References

[1]   Kuhnlein, H. V. and Receveur, O. Dietary change and traditional food systems of indigenous peoples. *Annual Review of Nutrition* 1996; 16: 117-142

[2]   Food and Agriculture Organization (FAO). *Promoting under-exploited food plants in Africa- A brief for policy makers.* FAO/UN, Rome; 1987.

[3]   Balandrin, M.F., Klocke, J. A., Wurtele, E. S & Bollinger, W. H. Natural plant chemicals: Sources of industrial and materials. *Science* 1985; 228: 1154-1160.

[4]   Nyam News. *Phytochemicals.* Caribbean Food and Nutrition Institute, Jamaica, W.I. 2005; (1) & (2): 1-4.

[5]   Culhane, C. *Nutraceuticals /funtional foods - an exploratory survey on Canada's potential (for Agriculture and Agro-food Canada).* Summary report, International Food Focus Limited Toronto ON.Ca; 1995 p9.

[6]   World Health Organization (WHO). *The world health report* WHO 2009, Geneva, Switzerland.

[7]   WHO *Diet, nutrition and the prevention of chronic diseases.* Report of a joint WHO/FAO Expert Consultation. Geneva, Switzerland; 2003.

[8]   Okeke, E. C., Mbah., B. N. & Nwosu, M. O. Field survey of indigenous African food crops and useful plants, food preparations from them and home gardens. UNU/

INRA Programme on Natural Resources Survey, Nairobi Kenya Series No. B5 (c); 1993.

[9]   Europa. Nigeria In: *Africa South of the Sahara*, 27th Edition; 1998. p780 – 806.

[10]   Maziya-Dixon, B., Akinyele, I. O., Oguntona, E. B., Sanusi, R. A. and Harris, E. Nigeria food consumption survey 2001 – 2003. Ibadan, Nigeria. IITA; 2004

[11]   Nicholas, K. Diabetes education and psychological care. *Practical Diabetes International* 1996; 13: 383- 355.

[12]   Federal Ministry of Health. National Expert Committee on Non-Communicable Diseases in Nigeria: Report of a national survey. Federal Ministry of Health, Lagos, Nigeria;1992

[13]   International Diabetes Federation (IDF) *Diabetes Atlas*, 2nd ed.. Brussels, IDF; 2003.

[14]   Hoet, J. J. The role of foetal and infant growth and nutrition in the causality of diabetes and cardiovascular disease in later life. Sub-Committee on Nutrition News 1992; 14: 10 - 13.

[15]   American Diabetes Association. Nutrition recommendations and principles for people with diabetes. (Position statement). *Diabetes Care* 1999; 22 Supplement 1.

[16]   Bennet, B. C. Plant as foods. Economy Botany. UNESCO-Encyclopedia of Life Support Systems (EOLSS); 2009.

[17]   Cleave, T. L. The neglect of natural principles in current medical practice. *Journal of the Royal Naval Medical Service* 1956; 42: 55-82

[18]   Burkitt, D. P., Walter, A. R. P & Painter, N. S. Dietary fibre and disease. *Journal of American Medical Association* 1974; 299: 1068-1074.

[19]   Olowokudejo, J. D., Kadiri, A. B. & Travih, V. A. An ethnobotanical survey of herbal markets, and medical plants in Lagos state of Nigeria. *Ethnobotanical leaflets* 2008; 12: 851-865.

[20]   Odugbemi, T. & Ayoola, A. Medicinal plants from Nigeria: an overview. In: Odugbemi, T. (ed.). *A text book of medicinal plants from Nigeria*. Lagos, Nigeria: University of Lagos press; 2008. p 9-17.

[21]   Fred-Jaiyesimi, A. A. & Ajibesin, K. K. Ethnobotanical survey of toxic plants and plants parts in Ogun state, Nigeria. *International Journal of Green Pharmacy* 2012; 6 (3): 174-179.

[22]   Chan, C., Ngoh, G. & Yusoff, R. A brief review of antidiabetic plants: Global distribution, active ingredients, extraction techniques and mechanisms. *Pharmacognosy Review*s 2012; 6 (11): 22-28

[23] Noor, A., Bansal, V.S. & Vijayalakshmi, M. A. Current update on anti-diabetic biomolecules from key traditional Indian medicinal plants. *Current Science* 2013; 104 (6): 721-727.

[24] Mukesh, R. and Namita, P. Medicinal plants with anti-diabetic potential- A review. *American – Euroasian Journal of Agriculture and Environmental Sciences* 2013; 13 (1): 81-94

[25] Osagie, A. U. and Eka, O. U. *Nutritional quality of plant foods.* Ugbowo, Benin City: Ambik Press; 1998.

[26] Thomas, B., editor. *Manual of Dietetic Practice.* Second edition. Oxford, London. Blackwell Scientific Publication; 1994.

[27] Soetan, K.O. Pharmacological and other beneficial effects of anti-nutritional factors in plants – a review. *African Journal Biotechnology* 2008; 7 (25): 4713-4721.

[28] Ivorra, M. D., Paya, M. & Villa, A. A review of natural products and plants as potential anti-diabetic drugs, *Journal of Ethnopharmacology* 1989; 27: 243-275.

[29] Drewnowski, A & Gomez-Carneros, C. Bitter taste, phytonutrients and the consumer: A review. *American Journal of Clinical Nutrition* 2000; 72, 1424-1435.

[30] Gibson, R. S. The role of diet-and host-related factors in nutrient bioavailability and thus in nutrient-based dietary requirement estimates. *Food and Nutrition Bulletin* 2007; 28 (1) (supplement): S77-S100

[31] Jenkins, D. J. A., Kendall, C. W. C., Marchie, A., Jenkins, L. A., Livia, S. A. A., Ludwig, D. S., Neal, D. B. & Anderson, J. W. Type II diabetes and the vegetarian diet. *American Journal of Clinical Nutrition* 2003; 78 (3): 610S – 616S.

[32] Champ, M., Langkilde, A., Brouns, F., Kettlitz, B & Collet, Y. Advances in dietary fibre characterization. 1. Definition of dietary fibre, physiological relevance, health benefits and analytical aspects. *Nutrition Research Reviews* 2003; 16: 71-82.

[33] McCarty, M. F. Proposal for a dietary "phytochemical index". *Medical Hypothesis* 2004; 63 (5): 813-817.

[34] Salijata, M.G., Singhal, R. S & Kulkarni, P. R. Rsistant starch: A review. *Comprehensive Review in Food Science and Food Safety* 2000; 5: 54-93.

[35] Vikas, K., Amit, K. S. Harinder, P. S. M. & Klaus, B. Dietary roles of phytate and phytase in human nutrition: A review. *Food Chemistry* 2010; 120: 945-959.

[36] Okeke, E. C. (1988). Dietary habits, nutrients intake and energy expenditure of low income rural farm households in the derived Savana area of Anambra State, Nigeria. Ph.D. Thesis, Department of Home Science and Nutrition, University of Nigeria, Nsukka.

[37] FAO. FAO production year book. Food and Agriculture handbook. Rome. FAO/UN 495; 1985.

[38] Enwere, N. J. *Foods of plant origin*. 1st ed. Nsukka, Nigeria: Agro–Orbis Publications; 1998.

[39] Ene-Obong, H. N., Sanusi, R. A., Udenta, E. A., William, I. O., Anigo, K. M., Chibuzo, E. C., Aliyu, H. M., Ekpe, O. O. & Davidson, G. I. Data collection and assessment of commonly consumed foods and recipes in six geo-political zones in Nigeria: Important for the development of a National Food Composition Database and dietary assessment, *Food chemistry* 2013 (in press) http://dx.doc.org/10./016/j.fdchem.2013.01.102.

[40] Okafor, J. C. Edible indigenous edible plants in the rural economy of the Nigerian forest zone. In: Okali, D. U. U. (ed). *The Nigerian rain forest ecosystem*. 1979. p262.

[41] Udenta, E.A., Thomas, J. and Ellis P. R. Documentation and botanical characterization of leguminous seed crops and polysaccharide plant materials used as thickening agents in Southern Nigeria. A final project report (FAO Project PR. 18496) presented to FAO at King's College, London in June, 2004.

[42] Ene-Obong, H.N. and Carnovale, E. Nigerian soup condiments: Traditional processing and potential as dietary fibre sources. *Food Chemistry* 1992; 43: 29-34.

[43] Uzo, J. O. Vegetable crops in Nigeria's agriculture. In: Mbah, B. N. and Nnanyelugo, D. O. (ed.) *Food crop production, utilization and nutrition*. Ibadan, Nigeria: Dotan publications limited; 1989. p39-44.

[44] Smith, I. F. Use of Nigerian leafy vegetables for diets modified in sodium and potassium. Nigerian Journal of Nutritional Sciences 1983; 4, 21-27.

[45] Dias, J. S. Nutritional quality and health benefits of vegetables: A Review. *Food and Nutrition Sciences* 2012; 3: 1354-1374.

[46] Garrow, J. S. and James, W. P. T. (eds.) *Human nutrition and dietetics*. 9th ed. Edinghburgh, United Kingdom: Churchill Livingston, 1998.

[47] Scrinivasan, K. Plant foods in the management of diabetes mellitus: Species as beneficial anti-diabetic food adjuncts. *International Journal of Food Sciences and Nutrition* 2005; 56 (6): 399-414.

[48] WHO. *Diagnosis and classification of diabetes mellitus and its complications*. Report of a *WHO consultation*. Part 1. World Health Organisation, Geneva (document WHO/NCD/NCS/99.2) (1999).

[49] American Diabetes Association (ADA). Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2012; 35 (Supplement 1) S64-S71

[50] WHO. *The global burden of disease*: 2004 Update. Geneva, Switzerland: WHO; 2008.

[51] International Diabetes Federation (IDF). Diabetes Atlas (3nd ed.). *Diabetes Voice* 2007; 52 (1), 46-48.

[52] Levitt, N. S. Diabetes in Africa: Epidemiology, management and healthcare challenges. In: Global burden of cardiovascular diseases. *Heart* 2008; 94: 1376-1382.

[53] Roglic, G., Unwin, N. & Bennett, P. The burden of mortality attributable to diabetes. *Diabetes Care* 2005; 28: 2130-2135.

[54] Sifelani, T. *Diabetes in Africa; A day in black history.* Harare, Zimbabwe; 2006.

[55] Mbanya, J. N., Motala, A. A., Sobngwi, E., Assah, F. K. & Enoru, S. T. Diabetes in sub-Saharan Africa. Lancet 2010; 375: 22254-2266

[56] Cooper, R., Rotimi, C., Kaufman, J., Owoaje, E., Fraser, H., Forester, T., Wilks, R., Riste, L. K. and Cruikshank, J. K.. Prevalence of NIDDM among populations of the African Diaspora. *Diabetes Care* 1997; 20.

[57] Wokoma, F. S. Hypertension in non-isulin dependent diabetes mellitus patients in Nigeria. *Diabetes International* 2002; 9 (3): 58.

[58] Popkin, B. M. The shift in the stage of Nutritional Transition in the Developing World Differs from past experiences. *The Journal of Public Health* 2002; 5:205-214.

[59] Geissler, B. & Powers, A. R. *Human nutrition.* Amsterdam ; Elsevier Applied Science Publisher; 2005.

[60] Evans, J.L., Goldfine, I. D., Maddux, B. A. & Grodsky, G. M. Oxidative stress and stress-activated signaling pathways: A unifying hypothesis of type diabetes mellitus. *Endocine reviews* 2002; 23: 299-622.

[61] Khan, A & Ahmed, I. Biochemical nature of diabetes mellitus. *Diabetes Journal* 1993; 5: 9-15.

[62] Shulman, G.I. Cellular mechanism of insulin resistance. *Journal of Chemical Investigation* 2000; 106, 171-176.

[63] Lipinski, B. Pathophysiology of oxidative stress in diabetes mellitus. *Journal of Diabetes Complications,* 15, 203-210.

[64] Halliwell, B. Anti-oxidant characterization, methodology and mechanism. Biochemical Pharmacology 1995; 49:1341-1348.

[65] Association for Dietetics in Southern Africa (ADSA) *Dietary management of patients with diabetes mellitus.* Position paper: 1996.

[66] Macdonald, I. Diabetes and hypoglycaemia: An update. *Carbohydrate* 1998; 9 (1): 1-3.

[67] Naidu, R. Dietary management of diabetes in Africa. (Review). *Diabetes International* 2000; 10 (1).

[68] Asif, M. The role of fruit, vegetables and spices in diabetes. *Journal of Nutrition, Pharmacology and Neurological Diseases* 2013; 1 (1): 27-35.

[69] Khan, A. & Safdav, M. Role of diet, nutrients, species and natural products in diabetes mellitus. *Pakistan Journal of Nutrition* 2003; 2 (1): 1-12.

[70] Onyechi, A. U., Judd, P. A. & Ellis P. R. African plant foods rich in non - sugar polysaccharides reduce post-prandial blood glucose and insulin concentrations in healthy human subjects. *British. Journal of Nutrition*, 1998; 80: 419 – 428.

[71] Odo, I. F. The post-prandial blood glucose response of diabetes to snacks (biscuits) developed from *Afzelia Africana* and plantain (Musa paradisiaca) flours. B. Sc. Thesis, Department of Home Science, Nutrition and Dietetics, University of Nigeria, Nsukka; 1998.

[72] Odenigbo, U. M. Incorporation of *Afzelia africana* (Akpalata) in Dietary management of Type 2 Diabetes mellitus in Nnewi, Anambra State, Nigeria. Ph. D. Thesis. Department of Home scienece and Nutrition, University of Nigeria, Nsukka; (2001).

[73] Onyechi, U. A. A comparative study of the effect of three plant foods high in soluble non starch polysaccharide on rat metabolism. *Nigerian Journal of Nutritional Sciences* 2009b; 30 (1): 122- 129.

[74] Kritchevsky, D. Dietary fibre. *Annual Review of Nutrition* 1988; 8: 301 - 328.

[75] Liu, R. H. Potential synergy of phytochemicals in cancer prevention: Mechanism of action. *The Journal of Nutrition* 2004; 134: 3479S-3485S.

[76] FAO/WHO/UNU. *Preparation and use of food-based dietary guidelines*. Report of a joint FAO/WHO Consultation, Nicosia, Cyprus. 1996. p.15-29

[77] Harden, K. E., Judd, P. A. & Hockaday, T. D. R. Glycaemic responses in type 2 diabetic patients to various mixed meals taken at home. *Diabetes Medicine* 1993; 10: 654-659.

[78] Ellis, P. R. The effect of fibre on diabetes. In: Hill M. (ed.). *The right fibre for the right disease*. International congress and symposium series, 236. London; The Royal Society of Medicine Press Ltd; 1999.

[79] Thompson, L. U., Button, C. L. & Jenkins, D. J. A. Phytic acid and calcium affect the *in vitro* rate of navy bean starch digestion and blood glucose response in humans. *American Journal of Clinical Nutrition* 1987; 46: 467-473.

[80] Iwu, M. M., Okunji, C. O. Aka, P. Diodcoretine: the hypoglycaemic principle of Dioscorea documentum tubers. Planta Medica1990; 56; 119-120.

[81] Gray, J. *Carbohydrates: nutritional and health aspects*. Europe: International Life Science Institute; 2003. p1-30.

[82] Jenkins, D. J. A., Wolever, T. M. S. & Taylor, R. H. Glycaemic index of foods: a phys-iological basis for carbohydrate exchange. *American Journal of Clinical Nutrition* 1981; 134: 362-366.

[83] Brennam, C. S. Dietary fibre, glycaemic response and diabetes. *Molecular Nutrition and Food Research* 2005; 49: 560-570.

[84] Augustin, L. S., Franceschi, S., Jenkins, DJA., Kendall, C. W. C., & La Vecehia, C. Gly-caemic index in chronic disease: A Review. *European Journal of Clinical Nutrition* 2002; 56: 1049-1071.

[85] Mendosa, D. The glycaemic index. Mendosa.com living with diabetes (no date).

[86] Nugent, A. P. Health properties of resistant starch. *British Nutrition Foundation Nutri-tion Bulletin* 2005: 30, 27-54.

[87] Englyst, K. N., Vinoy, S., Englyst, H. N. & Lang, V. Glycaemic index of cereal prod-ucts explained by their content of rapidly and slowly available glucose. *British Journal of Nutrition* 2003; 89: 329-339.

[88] Berry, C. S. Resistant starch, formation and measurement of starch that survives ex-haustive digestion with amylolytic enzymes during the determination f dietary fibre. *Journal of Cereal Science* 1986 ; 4: 301-314.

[89] Atawodi, S. E. Anti-oxidant potential of African medical plants. *African Journal of bio-technology* 2005; 4 (2): 128- 133

[90] Eleazu, C. O & Okafor, P.N. Anti-oxidant effect of unripe plantain (*Musa paradisica*) on oxidative stress in alloxan-induced diabetic rabbits. *International Journal of Medi-cine and Biomedical Research* 2012; 1 (3): 232-241.

[91] Bosch, C. H., Siemonsma, J. S. Lemmens, R. H. M. J. & Oyen, L.P.A. Plant resources of tropical Africa basic list of species and commodity grouping. PROTA Programme. Wageningen, The Netherlands: 2002. p7-12.

[92] Ogbu, J. U., Essien, B. A. Essien, J. B. & Anaele, M. U. Conservation and management of genetic resources of horticultural crops in Nigeria: Issues and biotechnological strategies. *Journal of Horticulture and Forestry,* 2010; 2 (9): 214-222.

[93] Adejuwon, J. O. Biotic resources. In: Ajaegbu, H. I. St. Mathew-Daniel, B. J. & Uya, O. E (eds). Nigeria: *A people united, a future assured*. Calaber; Gabumo publishers: 2000. p91-96.

[94] Kuhnlein, H., Erasmus, B., Cree-Kanashiro, H., Englberger, L. Okeke, C., Turner, N., Allen, L. & Bhattacharjee, L on behalf of the whole group. Indigenous peoples' food systems for health: finding interventions that work. *Public Health Nutrition 2006*; 9 (8): 1013-1019.

[95] Boogmans, B. Ethnobotanical survey of West African vegetable food in the Nether-lands. NHN, Leiden University. (no date).

[96] Cheng, J. T. & Yang R.S. Hypoglycaemic effect of guava juice in mice and human subjects. *American Journal of Clinical medicine* 1983; 11 (1-4): 74-76.

[97] Jimenze-Escrig, A., Rincon, M., Pulido, R., & Saura-Calixto, F. Guava fruit (*Psidium guajawa* Linn.) as a new source of anti-oxidant and dietary fibre. *Journal of Agricultural and Food Chemistry* 2001; 49: 5489-5493

[98] Alyegba, S. S., Roy, M. & Ioryem, D. B. Ethnobotamical survey of edible wild plants in TIV communication of Benue state, Nigeria. *Journal of Natural Science Research* 2013; 3 (7): 17

[99] Woolfe, M. L., Chaplin, M. F., & Otchere, G. Studies on mucilages extracted from okra fruits (*Hibiscus esculentus* L.) and baobab leaves (*Adansonia digitata* L.). *Journal of the Science of Food and Agriculture* 1977; 28 (6): 519-529.

[100] Ibeanu, V. N., Onyechi, U. A., & Ugwuanyi, G. U. Nutrient and dietary profile of dehulled and undehulled seeds of sweet princess water melon (Citrullus lanatus) consumed in Nigeria. *International Journal of Basic and Applied Sciences* 2012; 12 (6): 249-252.

[101] Eseyin, O. A., Oforah, E., Dooka, B. D. Preliminary study of hypoglycaemi action of the extract of leaf of *Telfairia occidentalis* in normoglycaemic guinea pigs. *Global Journal of Pure and Applied Science* 2000; 6: 639-641.

[102] Onyeka, E. U. & Nwambekwe, I. O. phytochemical profile of some leafy vegetables in South-east, Nigeria. *Nigerian Food Journal* 2007; 25 (1): 67-76

[103] Nwanjo, H. U. Efficacy of aqueous leaf extract of *Vernonia amygdalina* on plasma lipoprotein and oxidative status in diabetic rat models. *Nigerian Journal of Physiological Sciences* 2005; 20 (1-2): 39-42.

[104] Adetunji, F. O. Anti-oxidant degradation in six indigenous okra *Abelmoschus esculentus* (L) Moench varieties during storage in Nigeria. *Journal of Food Technology* 2008; 6(5): 227-230.

[105] Zhenzhong, X., & Hongium, S. Effects of okra capsule combined with valsartan in treatment of early diabetic nephropathy with microalbuminuria. *Modern Journal of Integrated Traditional Chinese and Western Medicine* 2010; 3.

[106] Tanya, A.K. N., Mbofung, C. M. F. & Keshinro, O.O. Soluble and insoluble fibre content of some Cameroonian foodstuffs. *Plant Foods for Human Nutrition* 1997; 51: 199-207.

[107] Fahey, J. W. Moringa oleifera: A review of the medical evidence for its nutritional therapeutic and prophylactic properties. Part I. *Trees for Life Journal* 2005; 1(5).

[108] Rao, M. U., Screenivasulu, M., Chengalah, B., Reddy, K. J. &Chetty, C. M. Herbal medicines for diabetes mellitus: A review. *International Journal of PharmTech Research* 2010;. 2 (3): 1883-1892.

[109] Rotimi, S.O., Olayiwola, I. Ademuyiwa, O & Adamson, I. Improvement of diabetic dyslipidemia by legumes. *African Journal of Food, Agriculture, Nutrition and Development* 2013; 13 (2): 7606-7623

[110] FAO. *Legumes in human nutrition*. No. 20, Rome; 1982.

[111] Adamson, I., Okafor, C. & Abu, B. A. A supplement of dikanut (*I. gabonensis*) improves treatment of type 2 diabetes. *West African Journal of Medicine* 1990; 9: 108-115.

[112] Udenta, E. A. and Obizoba, I. C. Physico-chemical profile and *in vitro* glycaemic index of two under-utilized leguminous seeds used as soup thickeners in Nigeria. A paper presented at the Nutrition Society of Nigeria 42nd Annual General Meeting and Sientific Conference on "Nutrition, Food Security, MDGs and National Development" held at Nelrose Hotel, Asaba, Delta State, Nigeria from 18th-22nd September, 2012. Book of Abstract 2012pT47: p67.

[113] Adebayo, S. A., & Oladele, O. I. Medicinal values of kolanuts in Nigeria: Implications for extension service delivery. *Life Science Journal* 2012; 9(2): 887-891.

[114] Monago, C. C., & Alumunah, E. O. Anti-diabetic effect of chloroform-methand extract of *Abrus precatorius* Linn seed in alloxan diabetic rabbits. Journal of Applied Science, Environment and Management 2005; 9 (1): 85-88

[115] Wireko-Manu, F., Maxiya-Dixon, B., Asiedu, R., Oduro, I. & Ellis, W. O. Exploiting the health benefits of water yam; its total dietary fibre composition.. A paper presented at the Nutrition Congress Africa 2012, held at University of the Free State, Bloemfontein, South Africa, from 30th September – 4th October, 2012. Book of Abstract 2012: p118.

[116] Onwurah, I. N. E. Crystallinity and polysaccharide chains of β-glucan in white sorghum, SK$_{5912}$. *International Journal of Biological Macromolecules* 2001; 29: 281-286.

[117] Saleh, A. S. M., Zhang, Q, Chen J. & Shen, Q Millet grains: Nutritional quality processing and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety* 2013; 12: 281-295.

[118] Dyles, L., & Rooney, L. W. Sorghum and millet phenols and anti-oxidants. *Journal of Cereal Science* 2006; 44: 236-251.

[119] Babu, P. D., Subhasree, R. S., Bhkyraj, R. &Vidhhylaksmi, R. Brown rice- beyond the colour reviving a lost health food- A review. American-Eurasian Journal of Agronomy 2009; 2 (2): 67-72.

[120] Udenta, E. A. and Obizoba, I. C. Physico-chemical profile and *in vitro* glycaemic index of *Candida tropicalis* fermented Nigerian starchy staple flours. A paper presented at the Nutrition Congress Africa 2012, held at University of the Free State, Bloemfontein, South Africa, from 30th September – 4th October, 2012. Book of Abstract 2012: p112.

[121] Olowu A.O., Adeneye, A. A. & Adeyemi, O. O. Hypoglycaemic effect of *Ipomea batatas* acqueous leaf and stem extract in normal and streptozotocin-induced hyperglycaemic rats. *Journal of Natural Pharmaceutics,* 2 (2), 56-61.

[122] Onyechi, U. A. The effect of *Detarium macrocarpium* soup meal on the plasma glucose and insulin levels of healthy non-diabetic adults. *Nigerian Journal of Nutritional Sciences* 2009a; 30 (1): 10 – 18.

[123] Onyechi, U. A. The physiological effect of *Detarium* bread meal on the post-prandial profile of non-insulin dependent diabetes mellitus (NIDDM) subjects. *Nigerian Journal of Nutritional Sciences* 2010; 31 (1): 47-52.

[124] Ngwu, E. K., Ndiokwelu, I.C, Ibaro, U. & Nwachi, I.C. Effect of African yambean gruel consumption on the health characteristics of diabetics in a rural community. *Journal of Dietitians Association of Nigeria* 2011: 3.

[125] Ana, A. 'A *taste of Calabar' selected Efik recipes to warm your stomach*. Gazeen, Lagos. 2000.

[126] Ani, A. I., Atangwho, I. J., Agiang, M.A. & Alozie, Y.E. Biochemical effects of some traditional Nigerian diets in experimental diabetic rat models. *International Journal of Biochemistry Research* 2012; 2 (2): 70-77.

[127] Fasanmade, A. A. & Anyakudo, M. M. C. Glycaemic indices of selected Nigerian flour meal products in male type 2 diabetic subjects. *Diabetologia Croatica* 2007; 36 (2): 33-38.

[128] Ikewuchi, C. C. & Ikewuchi, J. C. Rate of *in vitro* digestion of some Nigerian foods by salivary α-amylase: implications for the management of post-prandial glucose levels. *The Pacific Journal of Science and Technology* 2009; 10 (2): 835-841.

[129] Ikem, R. T. Kolawole, B. A., Ojofeitimi, E. O. Salawu, A. Ajose, O. A. Abiose, S. & Odewale, F. A. Controlled comparison of a high fibre diet on the glycaemic and lipid profile of Nigerian clinic patients with type 2 diabetes. *Pakistan Journal of Nutrition* 2007; 6 (2): 111-116.

[130] Udenta, E. A., Ohagwa, H.O., Mbah, U. C., Odo, A.U. & Obizoba, I.C. Effects of anti-diabetic diets based on fermented cassava, maize and sorghum and unfermented *Cola gigantea* on biochemical composition of diabetic adult rats. A paper presented at the 2nd Federation of African Nutrition Societies on "Accelerating Nutrition Actions for Africa's Development" held at International Conference Centre, Abuja, Nigeria from 11th-15th September, 2011