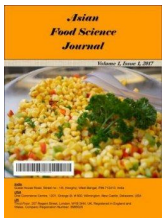

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A Review on Bioactive Compounds of Yam Varieties for Human Disease Management

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Authors' contributions

This work was carried out in collaboration between all authors. Author ANK designed the study, and wrote the first draft of the manuscript. Authors ANK, CVE and NPO managed the literature searches, and also read and approved the final manuscript.

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ABSTRACT

Bioactive compounds are secondary metabolites found in plants other than the nutrient in a plant that has health benefits to the consumers. These compounds in the plant have different structure and functions. Some of the functions are antioxidative, antihypertensive, anti-inflammatory, antidiabetic etc, Yams are edible tuberous roots which belong to Dioscorea family, and are rich in bioactive compounds such as phenol, saponin, the bioactive peptide, Discorin and diosgenin. Discorin, and Diosgenin are main bioactive compounds. These compounds have therapeutic properties which improve and change health status of an individual. Their therapeutic properties are pronounced when the bioactive compounds have been extracted. This improves its efficacy and gives it an opportunity to act better.

Keywords: Disease management; bioactive compounds; dioscorea.

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1. INTRODUCTION

Since antiquity, when there were little or no drugs to take care of the abnormal conditions of the bodies. Man has used plants, herbs, roots and shrubs to treat common infectious diseases. Some of these traditional medicines are still included, as part of the habitual treatment of various diseases [1]. The efficacy of the plant used by our forefathers is as, a result of the presence of some compounds with health benefits. These compounds are known as 'BIOACTIVES'. Bioactive compounds are plants secondary metabolites that are not needed for the daily function, of the plant but can be used by the plant for defence and attraction [2]. They are compounds in food other than those necessary, to supply the basic nutritional need. They are responsible for changes in health status of an individual [3]. It is important to understand that bioactive compound in food are not food nutrient, even though they are contained in food or are part of the food constituents. They trigger responses from an effect on the human body, the effect can be a positive or a deleterious one[4]. During the past few years plant such as rapeseed, potato, yam etc, with chemical and biological activities have been investigated to expose novel and more effective therapeutic compounds [2,5]. According to Lawal et al. [6] yam is considered a herbal medicine in Taiwan.

Yam belongs to Dioscorea family; economically it is an important food in many tropical countries where it also has a social and cultural benefit [7]. Yam tuber is a staple food in most parts of West Africa, including Nigeria where it is a premium crop in the food system [8]. It is a highly valued crop which forms, about 10% of the total roots and tuber produced in the world. According to Lawal et al. [6], about 30 million tonnes are produced in the world, of which Nigeria alone produces 22 million tonnes. Over 600 species of yam exist in different part of the world [9,10]. Ten out of the yam species are known to be edible. The most cultivated species are the Dioscorea rotundata (white yam), Dioscorea alata (water yam), Dioscorea dumetorum (bitter yam), Dioscorea esculentum (loir), Dioscorea cayenensis (yellow or guinea yam) and Dioscorea bulbifera (aerial yam). White or guinea yam (D. rotunduata poir) is the most popular species in Africa [6,11].

Yam as edible tuberous roots, vary in taste from sweet to bitter to tasteless and are mostly eaten as cooked starchy vegetables. It is often boiled and then mashed; they may also be fried, roasted, baked, pounded into a thick paste after boiling (pounded yam) and is eaten with soup or can be processed into yam chips and flour for confectionaries. It has been reported by Lee et al. [12] that yam tuber can be sliced and used as herbal medicine in China. When compared to other tropical root crops, it is said to be of a higher nutritional superiority. They have been researched on as, a good source of essential dietary nutrients and a major contribution to the nutrition of West African as a source of carbohydrate, energy, vitamins (especially vitamin C), minerals and protein. Some varieties of yam-like have been reported to contain protein in the level of 3.2-13.9% in dry weight [13-15]. It also contains other compounds such as peptide, phytochemical, polyphenols etc. which confers healing to the consumer and disease management.

Disease can be defined as abnormal conditions or disorder of a structure or function that affects part or all of an organism. It can be said to be intrinsic when it is caused by internal factors such as pathogen or extrinsic when it is caused by an external factor such as dysfunction of the body. Whatever be the cause, disease still remains an abnormality of the human body. Due to some challenges associated with synthesized drugs such as: higher incidence of adverse drug reactions, [16] impurities, over usage, multiple drug resistance to human health and resistant strains of antibiotics in the case of infectious diseases. Men turned to ethno pharmacology where phytochemical from numerous plants are used as a better alternative [17]. The use of bioactive compounds as a chemotherapy will be an alternative to non-synthetic drugs. As reported by Dey et al. [18] Dioscorea alata has anti-inflammatory, Purgative, diuretic, anti-rheumatic properties. This can be supported by the work of Sakthidevi and Mohan [19] who reported that *D. alata* can prevent cancer, reduce blood sugar and diabetes. The objective of this review is to highlight the bioactive compounds in yam that have disease management implication properties in human.

2. BIOACTIVE COMPOUNDS

Bioactives are secondary metabolites that are synthesized by plant and used as a defence mechanism against pests. According to Sonarkar and Purb [20] bioactive compound is a material that has the effect on, or eliciting a response from living tissue/organism. It can be synthesized

in different parts of the plant. Point of synthesis may not necessarily be the point of accumulation. Bioactive compound such as terpenoids and essential oils; phenolics and polyphenols; alkaloids; polypeptides (crude extract) exist as antimicrobial compounds [21]. The bioactive compounds studied most extensively are the antioxidants, an increased intake of which can alter the risk of chronic diseases including cancer and cardiovascular disease.

2.1 Bioactive Compounds in Yam

Yam is known to contain a good quantity of bioactive compounds, such as phytochemicals in form of (Alkaloids, Tannis, flavonoids, saponins, glycoside steroids, Anthraquinones etc), polyphenols (flavonoids and phenolic acids), phenols. Dioscorin and Diosgenin are the most predominant of the phytochemicals found in yam.

2.1.1 Diosgenin

Diosgenin is a bioactive steroidal sapogenin which belongs to the triterpene group [22]. Diosgenin is of a great interest to the pharmaceutical industries, in that is constitute the pharmaceutical agent. It is known to prevent colon cancer, decrease cholesterol absorption and also used in the manufacturing of drugs such as cortisone, hormonal drugs [23]. Diogenin and its glycosides is the typical bioactive compound for Dioscorea family. These compounds are detected in Chinese yam [24]. *Dioscorea rotundata, Dioscorea esculeta, Dioscorea dregeana*, contains diosgenin which exhibited antimicrobial and anti-inflammatory activities to gram positive and gram negative bacteria [25].

2.1.2 Saponins

They act as natural antibodies; some general properties of saponins include the formation of foams in aqueous solution, hemolytic activity and cholesterol binding properties. Saponin anti-microbial activities make it good for treating fungal and yeast infections. It has been reported that Dioscorea bulbifera contains saponin [26].

2.1.3 Dioscorin

This is a storage protein found in some species of yam which functions as trypsin inhibitor, carbonic anhydrase, antioxidant, immunomodulator, and ant hypertension invasion [27]. It accounts for over 90% 0f extractable proteins in yam. *Dioscorea opposita* Thunb tuber *mucilage, Dioscorea alata, Dioscorea japonica, Dioscorin esculenta, Dioscorea babata* etc. contain diocorin. Several species of *Dioscorea* are among the main sources of diogenin.

2.1.4 Water- soluble polysaccharides (WSP)

WSP of yellow and white water yam could be used to reduce the blood glucose and cholesterol levels (especially the low-density lipoprotein cholesterol) due to the presence of glucomannan [27]. There are abundant water-soluble polysaccharides in Dioscorea opposite Thunb that, have demonstrated hyperglycemic properties. According to Yijun [28] water -soluble polysaccharide extracted from yam tuber (D. *hispida*) was shown to demonstrate glucose lowering ability, in hyperglycaemic condition as well as inhibit absorption of glucose and short chain fatty acids when fed to mice. Also the WSP has the ability to improve the immune system. The immune system functions as the defence mechanism of the body, against invaders and any foreign bodies. It eliminates infectious microbes, viruses, and tumours that will attack the body [29]. The immune system comprise of macrophage, lymphocytes, natural body killers. Lin and Xin [30] reported an increase in lymphocyte, macrophage and natural cell killer (NK cell) when water-soluble polysaccharides extracted from Dioscorea opposite Thunb was administered to an experimental mouse.

2.1.5 Tannin

Tannin is non-toxic and can generate physiological responses in animals. It plays a major role as antifungal, antidiarrheal, antioxidant and anti hemorrhoidal [6]. Red, orange and yellow cultivars of *D. bulbifera* contain tannin and phenols.

2.1.6 Flavonoid

This is widely distributed antioxidants and are present in medicinal drugs, fruits and vegetables (food) e.g. propolis, wine, chocolate and yam. *Dioscorea alata* and *Dioscorea cayennesis* contain flavonoids, phenolic compounds in the proportion of; 410.52 mg/100 (flavonoid) and 13.10 mg/100 (total phenols) and 150.67 (flavonoids) and 3,43 mg/100 (total phenols) for *Dioscorea alata* and *Dioscorea cayennesis* respectively, which exhibit free radical scavenging activities [31].

2.2 Extraction of Bioactive Compounds in From Yam

Extraction pharmaceutically refers to the separation of medicinal active components in a plant from the inactive compound by the use of selective and special solvents. In the utilization of phytochemical in the production of dietary supplement, nutraceuticals, as a food ingredient, pharmaceutical and cosmetic product, the bioactive compounds must be extracted as the first step [31]. Bioactive components used as dietary supplement, pharmaceutical, nutraceutical can be extracted from fresh, dried or frozen plant materials. Method of extraction includes: conventional method and modern method.

2.2.1 Conventional method

The conventional method of extraction involves the following:

2.2.1.1 Soxhlet

This method of extraction was formally designed to extract lipid and it is now the common method of extracting bioactive compounds.

2.2.1.2 Maceration

Is a traditional method of extraction that is not expensive but popular and is usually carried out in a closed vessel with milled plant material.

2.2.1.3 Hydro-distillation

This is a traditional method of extraction for bioactive compounds and essential oils can be divided into three types; water distillation, water and steam distillation and direct steam distillation. Hot water and steam are used as the main solvents to extract bioactive compounds from plant tissue [29]. The conventional methods for extraction of bioactive compounds in yam such as phenol, was reported by Eleazu et al. [32].

2.2.2 Modern extraction technique

These methods were developed as a result of disadvantages in the traditional method of extraction. It includes solid-phase micro-extraction, supercritical-fluid extraction, pressurized-liquid extraction, microwave-assisted extraction, solid-phase extraction, and surfactant-mediated techniques, which possess certain advantages [33]. Shah and Lele [22] extracted Diosgenin from *D. alata* by acidic hydrolysis of the glycosides which was followed by the HPTLC analysis.

Different solvents and techniques are used for the extraction of polyphenols from plants. The technique which is used for the isolation of phenolic compounds from plant material mainly depends on the type of polyphenolic compound. The solvent used for the extraction has an effect on the recovered extract [34].

2.3 Bioactive Compounds in Yam and Their Use for Disease Management

2.3.1 Anti hypertensive Bioactive

Hypertension is a chronic condition which has been reported to have been being the major risk factor for CVD, stroke, the end stage of renal disease and premature death globally [35]. This is the stiffening of the blood passage thereby not allowing the free flow of blood. The systolic blood pressure is persistently at 140 mmHg or above and the diastolic at 90 mmHg.

2.3.1.1 Mechanism of Action

The nervous system, the kidney and the rennin-angiotensin system (RAS) control the blood pressure while having the RAS as the major regulator of the blood pressure, maintenance of blood pressure, homeostasis, fluid and electrolyte balance in the human body. The two enzymes that control the RAS are the rennin and the angiotensin 1 converting enzyme (ACE). Renin converts angiotensinogen to angiotensin I. The angiotensin I is subsequently converted to angiotensin II by ACE. Angiotensin I-converting enzyme (ACE) catalyzes the hydrolysis of angiotensin I, an inactive decapeptide, to angiotensin II, while ACE catalyzes the conversion of angiotensin 1 to angiotensin 11. At this point vasodilator which function is to regulate the biological processes in the body such as the release of nitric oxide, oxidative stress is inactivated. The ACE 11 causes sodium and fluid to be retained in the vessel. The presence of bioactive peptide such as protein-derived peptide in yam acts as an inhibitory agent against ACE. This has physiological effect on human being and effectually affects their health. Hou et al. [36] reported food-derived peptides, which were hydrolyzed by pepsin, trypsin, or chymotrypsin, including R-lactalbumin and lactoglobulin, casein, zein, and gelatin is known to inhibit ACE. Also

fermented milk was also reported to exhibit ACE inhibitory activity. Mc Anuff et al. [37] reported that sapogenin extract from bitter yam has the ability of to decrease fasting blood glucose.

2.3.2 Anticancer bioactive compounds

Development of cancer involves different stages which include initiation, promotion, progression, invasion and metastasis. The initiation of tumor begins when DNA is damaged by the presence of carcinogens as a result of inflammation during cell promotion. The initiated cell expands to form actively proliferated multicellular population of tumour cells. This is an interruptible or reversible and long-term process. In the last stage of cancer invasion-metastasis set in. At this stage the tumor cell detaches from the parent tumor mass and moves to the blood vessel or lymphatic vessel and forms a second lesion. The inhibitory effect of natural phenolics in carcinogenesis and tumour growth may be through these mechanisms:

1) Modifying the redox status and,
2) Interfering with basic cellular functions (cell cycle, apoptosis, inflammation, angiogenesis, invasion and metastasis).

The most outstanding function of saponin is in the destruction of cancer cells, where it interferes with cell growth and division. This is done without having any negative effect on the normal cells. Unlike some non-synthetic cancer-fighting drugs that destroy normal cell [38]. Cancerous cell is known to have much cholesterol. Alkaloid and Diogenin posse chemopreventive action against chronic inflammation associated with cancer cells as demonstrated by Okwu et al. [39]. The chemopreventive action against cancer cells is achieved by alteration of lipid metabolism (lowering of blood triglycerides as assisted by lipoprotein lipase).

2.3.3 Bioactive antioxidant

Free radicals and reactive oxygen species such as hydroxyl radical (OH), peroxyl radical (ROO), singlet oxygen (O2), hydrogen peroxide (H2O2), lipid hydrogen peroxide (LOOH) and superoxides radical (O2) have been the major cause of oxidation in human body causing cardiovascular diseases, diabetes mellitus, hypertension, cancer etc. but the presence of antioxidant as free radical scavenger have prevented the action of these free radicals inhibiting their activities and also oxidative damage. ROS (Reactive oxygen species) is produced by normal cellular metabolism that occurs daily in the body or through exogenous activities like metabolism of environmental toxin or ionic radiation. As ROS is produced and increases in the body at a point it suppresses the activities of the enzymatic antioxidant (endogenous antioxidant) like the glutathione (GSH), ascorbate, catalase, superoxide dismutase which are the endogenous antioxidant defence system. In the initiation stage of ROS and free radical, the superoxide radical is produced and is converted to hydrogen peroxide. This is further broken down to water in the presence of some minerals (such as copper, zinc, manganese and iron) and later oxygen molecule by an endogenous antioxidant known as superoxide dismutase [40]. At a stage when there is an excessive production of ROS and free radical, the action of the endogenous antioxidant (superoxide dismutase, catalase, glutathione etc.) becomes ineffective. This causes the superoxide to be converted to hydrogen peroxide and which is later converted to hydroxyl radical that is toxic. At this point oxidative stress occurs, leading to lipid, protein, and DNA damage. Food derived peptide has effect against ROS and free radicals. Their activities include;

(1) Up regulating the function of endogenous antioxidants such as reduced glutathione (GSH), ascorbate, superoxide dismutase and catalase
(2) Scavenging of radical species such as ROS/RNS and free radicals by readily donating hydrogen atoms or electrons to quench their destructive effects on bio molecules,
(3) Suppression of ROS/RNS and free radical formation

To further strengthen the health benefit of bioactive compounds in yam it has been reported that polyphenol in form of flavonoid and the presence of vitamin C show antioxidant properties [41]. The antioxidant activity of a phenolic compound is due to its ability to scavenge free radicals. Dioscorin found in D. alata and also other yam species possess antioxidant properties [42,43].

2.3.4 Antimicrobial bioactive

Antimicrobial bioactivity in yam is due to the presence of phenolic acids, flavones, flavonoids, flavonols, tannins etc. They are produced by plant in responds to microbial infection. They serve as plant defence mechanism against

organism foreign body. The toxic nature of phenol to microorganism is attributed to the sight and the number of hydroxyl group present in the phenolic group [44]. Alkaloids are seen as the most effective phytochemicals because of the presence of nitrogen which is the building block of amino acid. This can be demonstrated by their analgesic, antispasmodic and antibacterial properties. It has been reported that flavonoids, triterpenes and steroids have shown significant activity against different strains of Staphylococcus aureus, Streptococcus faecalis. Flavonoid has also been used against fungal pathogen of man due to its ability to inhibit spore germination of plant pathogen [44,45]. According to *Lopez* et al. [46] Steroidal saponins isolated from *D. villosa* are considered to be an important source of antifungal properties. Other glycosides of diosgenin found in the *D. villosa* includes three spirostane saponins which actively inhibited Candida albicans and other human pathogenic yeasts in vitro.

2.3.5 Immunomodulatory bioactive

The immune system has attracted a lot of attention as a result of the numerous chronic diseases. Immunomodulation involves suppression or stimulation of human immune functions. The immune system contains the macrophage, lymphocytes and dendritic cell, natural cell killer (NK). The macrophage and the dendritic present to the T cell of the immune system, process antigen while the natural cell killer is responsible for the control of cytotoxic activities and also control the virus- infected cells and tumour. Lymphocytes produce an antibody that fights against antigens. Alkaloids, terpenoids, tannins, saponins, glycosides, flavonoids, phenolics, steroids, bioactive peptide have immunomodulatory property by enhancing the functions of the immune system including regulation of cytokine expression, antibody production [36,47]. Whey peptide released from enzymatic hydrolysis is known to increase the activities of lymphocytes and its proliferation [48]. Alkaloids, terpenoids, tannins, saponins, glycosides, flavonoids, phenolics, steroids, and peptide upgrade the activity of the immune system by causing more production of cytokine which is the main regulator of the immune system.

2.3.6 Hypolipidemic and hypo-cholesterolemic bioactive

Metabolic syndrome if not controlled is the main risk factor of cardiovascular diseases. The secondary metabolite, polyphenols, polyunsaturated fatty acid, dietary fibre, protein are used to ameliorate the abnormal metabolic processes related to metabolic syndrome. It was reported by Akindele et al. [49] that Dioscorea nipponica (DN) powder at 5% level demonstrated a suppression of the body weight gain of an experimental animal when DN powder was administered to the rat. This could be as a result of the presence DN powder which contains various steroidal saponins and sapogenins (including diosgenin). This can be supported by the work of Lin et al. [50] who reported that bitter yam steroidal extract resulted in lowering of the cholesterol, LDL and subsequent increase in the HDL Protease-aided hydrolysis of food proteins (bioactive peptide) can also release peptide sequences that possess cholesterol and lipid-lowering activities etc. [47]. Yam as a source of dietary fiber prevents the absorption of fat in the intestine thus resulting to the lowering of LDL.

2.3.7 Antidiabetic bioactive

Diabetes is a metabolic disorder associated with elevated blood glucose level and excretion of glucose from the urine. Diabetes occurs as a result of the destruction of pancreatic β-cell which eventually leads to non responsiveness of insulin [45]. The main cause of Type 1 diabetes is autoimmunity, through the destruction of insulin-producing β-cells in the pancreas. Type 2 diabetes is caused by increased apoptosis, non responsiveness of pancreatic cell and reduction of insulin. It is also associated with abnormal metabolism of protein, carbohydrate and lipids. The non responsiveness of insulin causes increase in the blood glucose level from the normal level of 80-120 mg/dl to 160 mg/dl which is known as hyperglycemia [51]. The treatment management of diabetes involves diet control, exercise and the use of insulin and oral hypoglycemic drugs. Management of diabetes with drugs usually have decreased efficacy over time, due to ineffectiveness against some long-term diabetic complications and low-cost effectiveness. Oral hypoglycemia drug with glucose lowering effect has been synthesized; this drug has imidazoline receptor. The imidazoline receptor is in three subgroup which are: the imidazoline receptor 1 which act by lowering blood pressure The imidazoline receptor 2 is used for pain modulation and the imidazoline receptor 3 play an important role in regulating insulin secretion from β-cells in the pancreas [52]. Use of these drugs is, however, limited by

the fact that they have adverse side effects, such as potential hypoglycemia (e.g. sulfonylurea), weight gain), gastrointestinal discomforts (alpha-glucosidase inhibitors, and alpha-amylase inhibitors). In addition to their potential side effects, many of the oral anti-diabetic agents have higher secondary failure. The use of plant extracts like saponin and flavonoids are better alternatives to synthetic drugs. The work of Udenigwe and Watt [53] demonstrated that Allantoin, a guanidine derivative, can be used to activate the 2 receptors to attenuate hyperlipidemia, improve hepatic steatosis and act as an antihypertensive agent. Also Diosgenin significantly decreased plasma glucose in streptozotocin-induced diabetic rats when it was administered for diabetic controls. This suggested its anti-diabetic properties. These results were further strengthened by the fact that several hepatic rate-limiting enzymes, commonly involved in glucose metabolism in a diabetic state were normalized by treatment with diosgenin [45]. Extract of *Dioscorea bulb* has inhibiting activity against alpha-amylase and alpha-glycosidase, thus helping to manage elevated blood glucose level [54]. These plants bioactive exhibit glucose lowering effect by:

1. Stimulation of insulin synthesis and secretion from pancreatic beta-cells,
2. Regeneration/revitalization of damaged pancreatic beta cells.
3. Improvement of insulin sensitivity (enhancement of glucose uptake by fat and muscle cells).
4. Mimicking the action of insulin (acting like insulin).
5. Alteration of the activity of some enzymes that are involved in glucose metabolism.
6. Slowing down the absorption of carbohydrates from the gut. Udenigwe and Watt [53] recorded that Diosgenin significantly decreased plasma glucose in streptozotocin-induced diabetic rats when it was administered for diabetic controls. This suggested its anti-diabetic properties. These results were further strengthened by the fact that several hepatic rate-limiting enzymes commonly involved in glucose metabolism altered in the diabetic state were normalized by treatment with diosgenin. Also, extract of *Dioscorea bulb* has inhibitory activity against alpha-amylase and alpha-glucosidase, thus helping to manage elevated blood glucose level [30].

2.3.8 Dyslipidemia bioactive

Dyslipidemia is the abnormality of the metabolic processes in the body which is characterized by elevated low density lipoprotein cholesterol, total cholesterol and decreased high density lipoprotein cholesterol. Phytochemical such as diosgenin has the ability to lower cholesterol level, in the elevated serum low-density lipoprotein (LDL) and high-density lipoprotein (HDL). Also, it lowers the plasma cholesterol in cholesterol-fed rat. This is achieved by preventing the absorption of cholesterol and increasing cholesterol secretion [55]. Food protein hydrolysate and peptides have hypolipidemic effect on dyslipidemia. Arginine containing peptides are known to be one of the contributing factors of the hypolipidemic property of food-derived peptides and hydrolysate. They act by disrupting micellar solubility and dietary cholesterol absorption. The acid bile circulation is altered which then increased cholesterol catabolism [56]. Harijono et al. [27] reported that Diogeninin a steroidal saponin has the ability to lower cholesterol level when diosgenin was extracted from yellow and purple yam fed to experimental rats.

3. CONCLUSION AND RE-COMMENDATION

3.1 Conclusion

It has been investigated that yam contains various bioactive compounds such as polyphenol, phenol, bioactive peptide with disease management ability which is a better alternative to synthetic drugs that, has some negative health implications associated with them.

3.2 Recommendation

It is important that we embrace yam and other plant materials with bioactive properties in order to reduce our over-dependence on non-synthetic drugs which have adverse effects on the body.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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