Chapter 9

Antioxidant Properties of Selected African Vegetables, Fruits and Mushrooms: A Review

R.U. Hamzah, A.A. Jigam, H.A. Makun and E.C. Egwim

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1. Introduction

Africa is blessed with vast amount of vegetables, fruits and mushrooms which are consumed for their nutrients or for their medicinal purposes. In recent years these vegetables, fruits and mushrooms have been shown to possess valuable antioxidants of great nutritional and therapeutic values. Antioxidants are substances which when present at low concentration compared to those of an oxidizable substrate [1] significantly delay or prevent the oxidation of that substrate. They are capable of preventing or attenuating damages such as lipid peroxidation, oxidative damage to membranes, glycation of proteins and inactivation of enzymes caused by free radicals. There are several evidences that show that oxidative stress resulting from reactive oxygen species including free radicals such as hydroxyl ($OH^{\cdot}$), superoxide ($O_2^{\cdot-}$), nitric oxide ($NO^{\cdot}$), nitrogen dioxide ($NO_2^{\cdot-}$), peroxyl ($ROO^{\cdot}$) and non free radical like hydrogen peroxide and singlet oxygen play an important role in the development of several pathological conditions such as lipid peroxidation, protein oxidation, DNA damage and cellular degeneration. These have been implicated in the aetiology of these pathological conditions related to cardiovascular diseases, diabetes, inflammatory diseases, cancer, Alzheimer and Parkinson disease, monogolism, ageing process and perhaps dementia [2,3-4, 5] .

Free radicals and other reactive oxygen species are constantly formed in the human body during normal cellular metabolism e. g during energy production in the mitochondria electron transport chain, phagocytosis, arachidonic acid metabolism, ovulation, fertilization and in xenobiotic metabolism [6]. They can also be produced from external sources such as food, drugs, smokes and other pollution from the environment [7]. Organisms are endowed with endogenous (catalase, superoxide dismutase, glutathione peroxidase/reductase) and exogenous (vitamin C, E, β-carorene) antioxidant defense system against reactions of free radicals. However the generation of free radicals in the body beyond its antioxidant capacity leads to oxidative stress which has been implicated in the aetiology of several pathological

conditions such as lipid peroxidation, protein oxidation, DNA damage and cellular degeneration related to cardiovascular disease, diabetes, inflammatory disease, cancer and parkinson disease [8]. As a result of this much attention is been focused on the use of antioxidants especially natural antioxidant to inhibit and protect damage due to free radicals and reactive oxygen species. Synthetic antioxidant such as butylated hydroxyanisole(BHA), tert-butylated hydroxyquinone and butylated hydroxytoluene have been of utmost concern to many researcher because of their possible activity as promoters of carcinogenesis[9] Plant based antioxidant are now preferred to the synthetic ones because of their safety.

Epidemiological studies have shown that the consumption of vegetables and fruits can protect humans against oxidative damage by inhibiting or quenching free radicals and reactive oxygen species [8].Many plants including fruits and vegetables are recognized as sources of natural antioxidants that can protect against oxidative stress and thus play an important role in the chemoprevention of diseases that have their aetiology and pathophysiology in reactive oxygen species (10, 11-12]. These positive effects are believed to be attributable to the antioxidants; particularly the carotenoids, flavonoids, lycopene, phenolics and β-carotene [13] Mushrooms which have long been appreciated for their flavour and texture are now recognized as a nutritious food as well as an important source of biologically active compounds of medicinal value [14]. Mushrooms accumulate a variety of secondary metabolites, including phenolic compounds, polyketides, terpenes and steroids. Also, a mushroom phenolic compound has been found to be an excellent antioxidant and synergist that is not mutagenic [15]. Studies have shown that tropical mushrooms are highly rich in proteins, minerals, vitamins, crude fiber and carbohydrate with low fat and oil content. The protein content of mushrooms has been reported to be twice that of vegetables and four times that of oranges and significantly higher than that of wheat [16, 17]. The high level of vitamins in mushrooms particurlary vitamin C and D has been reported as responsible for its antioxidative activity [17, 18]. Mushrooms contains also an appreciable quantities of crude fibres, although, little information exist on Total Dietary Fibre (TDF) content of mushrooms. The crude fibre content values reported from many studies suggest that mushrooms are potential sources of dietary fibre [16]. Mushrooms generally contain low fat and oil content [16]**.** Because of the low fat and oil content, they are recommended as good source of food supplement for patients with cardiac problems or at risk with lipid induced disorders.

Also a lot had been reported on the nutrient; antinutrient and mineral composition of some edible mushrooms in Nigeria [19, 20] however there are few reported data on the antioxidant properties of commonly consumed mushrooms. This Chapter is therefore intended to discuss the antioxidant properties of selected African vegetables fruits and mushrooms.

2 Antioxidant properties of selected vegetables

2.1. *Vernonia amygdalina* (VA)

Vernonia amygdalina is a perennial shrub that belongs to the *Asteraceae* family and is popularly called bitter leaf in English a. It is known as 'Grawa' in Amharic, 'Ewuro' in

Yoruba, 'Etidot' in Ibibio, 'Onugbu' in Igbo, 'Ityuna' in Tiv, 'Ilo' in Igala 'Oriwo' in Edo and 'Chusar-doki' in Hausa.It has petiolate leaves of about 6mm diameter and ellicptic in shape. The leaves are green with a characteristic odour and bitter taste [21]. They are well distributed in tropical African and Asia and are commonly found along drainage lines and in natural forest or commercial plantation.

In most part of Africa, the leaves of VA are used as soup condiments after washing or boiled to get rid of the bitter taste. Specifically it is used to prepare the popular Nigerian bitter leaf soup, "onugbo" and as spice in the Cameroon dish called "Ndole" [22].

VA has a long history of use in folk medicine particularly among the sub Saharan African. Huffman and Seifu [23] reported the use of VA in the treatment of parasite related disease in wild chimpanzee in Tanzania. This necessitated quite a great number of researches to test the efficacy of different part of the plant in managing a wide array of ailments [22, 24]. Many traditional medicine practitioners use different parts of the plants in treating various ailments for instance the whole plant is being used as antihelminth, antimalaria and as a laxative [25]. Others use the aqueous extract of the leaves as a digestive tonic, appetizer and for treatment of wounds [26]. The decotion from leaves is used in the treatment of malaria fever in Guinea and cough in Ghana [24]. The leaf is also in Ethiopia as hops in preparing beer [27]. In Malawi and Uganda it is used by traditional birth attendants to aid expulsion of placenta after birth, aid post-pertum uterine contraction, induce lactation and control postpartum haemorrhage.

Their traditional use is not limited to human alone, in northern Nigeria it has been added to horse feed to provide a strengthening or fattening tonic *chusan Dokin* in Hausa.

Different extracts of VA has been shown to posses antioxidant properties both invitro and invivo. Ayoola et al [28] showed the invitro antioxidant properties of the ethanolic extract of leaves of VA using the diphenyl picyryl hydrazyl radical (DPHH) scavenging test. *V. amygdalina* was shown to have moderate inhibition of 77.7% thus indicating the scavenging ability of the vegetable. Also the aqueous and ethanolic extract of VA has further been shown to have potent antioxidant properties as they were able to inhibit bleaching of B-carotene, oxidation of linoleic acid and lipid peroxidation induced by $Fe^{2+/}$ ascorbate in a rat liver microsomal preparation. This study showed that the antioxidant activity of the ethanolic extracts was higher than that of the aqueous extracts, and compared favourably with synthetic antioxidant BHT and BHA [29]. However another study reported that methanol extract displayed highest antioxidant activity followed by acetone and water extract [30].

Adesanoye and Farombi [31] reported the hepatoprotective activities of the aqueous extract of *Vernonia amygdalina* leaves against carbon tetrachloride-induced hepatotoxicity and oxidative stress in mice. Administration of *Vernonia amygdalina* resulted in accelerated reversion of hepatic damage via reduction of liver marker enzymes like ALT, AST, ALP, Lactate dehydrogenase and bilirubin. Similarly antioxidant enzymes such as superoxide dismutase, glutathione S-transferase and reduced glutathione concentration and catalase activity were increased significantly at different doses of the methanolic extract of VA. This

study is in agreement on previous work reported on the antioxidant properties of VA on aacetaminophen induced hepatotoxicity in mice [32]. The presence of flavonoids, phenols and other phytochemicals in this vegetable have been attributed to its antioxidant properties

Further confirmation of the antioxidant activities of VA was carried out by Oloyede and Ayila [33]. They investigated the antioxidant activity of different extracts, aqueous, methanol, hexane, ethylacetate and butanol extracts of *Vernonia amygdalina* using three methods: scavenging effect on 2,2-diphenyl-1-picryhydrazyl radical (DPPH), hydroxyl radical and peroxide oxidation by ferric thiocynate method. All fractions showed significant antioxidant activity ($p<0.05$) when compared with antioxidant standards like butylated hydroxyl anisole (BHA), ascorbic acid and α-tocopherol used in the assay. This plant contains natural antioxidants against aqueous radicals and reactive species ions [30].

Oxidative stress has been implicated in numerous human diseases including cancer, atherosclerosis, diabetes, malaria, iron overload, rheumatoid arthritis, Parkinson disease, and in HIV infection and AIDS [1]. This term actually refer to the imbalance between the generation of reactive oxygen species and the activity of the antioxidant defenses[34].Reactive oxygen comprises both free radicals such as hydroxyl (OH!), superoxide ($O_2^{\cdot-}$), nitric oxide ($NO^{\cdot}$), nitrogen dioxide ($NO_2^{\cdot-}$), peroxyl ($ROO^{\cdot}$) and lipid peroxyl ($LOO^{\cdot}$ And non free radical or oxidants like hydrogen peroxide (H_2O_2), ozone (O_3), singlet oxygen ($^1O^{\cdot}$), hypochlorous acid (HOCl), nitrous acid (HNO_3), peroxynitrite ($ONOO^-$), dinitrogen trioxide (N_2O_3), lipid peroxide (LOOH), oxidants, although, they can easily lead to free radical reactions in living organisms [35]. Many of these ROS serve useful physiological functions but can be toxic when generated in excess or inappropriate environment thus causing oxidative damage to membranes and enhanced susceptibility to lipid peroxidation or enzyme inactivation.

Vernonia amygdalina has been used in various part of Africa for the treatment of several ailments ranging from diabetes, malaria, cancer and for general wellbeing. This local treatment has been backed up in recent times scientifically.

Nwanjo [36] reported the antidiabetic effect of the aqueous extract VA in streptozotocin induced diabetic rats. He showed in his finding that VA was capable of reducing plasma glucose, triglycerides, and LDL-cholesterol and the marker of oxidative stress malondialdehyde. These may be due to decreased oxidative stress which may be via direct scavenging of the ROS or by increasing the synthesis of antioxidant molecule [37].

Recently Akpaso et al [21] showed that the antidiabetic effect of the combined leaf extracts of *vernonia amygdalina* (bitter leaf) and *Gongronema latifolium* on the pancreatic β – cells of streptozotocin – induced diabetic rats. The extracts were observed to increase the animal body weight against the loss in weight in the diabetic group. In the same manner the serum glucose significantly decreased after 28days of treatment with the combined extract. Regeneration of islets cells was explained to be the one of the possible cause as there will be an increase in insulin production and secretion [38]. Previous studies by Ebong et al [39] reported this possible synergestic action using the extracts of Azadirachta indica and VA. It has been clearly demonstrated that *Vernonia amygdalina* extract contains active ingredients

such as vernoniosides, glucosides, (VA) flavonoids and antioxidants [40] which may be responsible for their potentials in reversing pancreatic damage caused by STZ or alloxan in experimental animals. It was proposed that sesquiterpene lactones and the bitter principle of the plant may also be responsible for insulin production, stimulation and release of pancreatic islets from the beta-cells [41]. On the other hand, tannin, flavoniods glycosides and phytosterols of the plant may also act as alpha glucosidase inhibitor which contributed to the hypoglycemic effect of the plant.

Cancer has become a serious global problem. Prostate cancer and breast cancer are the most diagnosed non-skin cancers in men and women respectively. Breast cancer represents 15% of new cases of all cancers [42] while prostate cancer represents 15.3% of all cancers in men in the developed countries [43]. *V. amygdalina* Del. is increasingly becoming a strong contender for cancer management. Coumarins, flavonoids, sesquiterpene lactones and edotides may be the principles in VA that are responsible for its anticancer activity [44-46].

It was reported that the aqueous extract of VA exhibited a cytotastic action on cultured human breast tumour cells (MCF-7) growth in vitro. This implies tumour stabilization or preventive effects in vivo [46]. Fractions of *Vernonia amygdalina* extract were found to inhibit DNA synthesis. However the physiological concentrations of the water-soluble *Vernonia amygdalina* extract potently inhibited DNA synthesis in a concentration-dependent manner both in the presence and absence of serum [27]. It was also reported that fractions of hexane, chlorofrm, butanol and ethylacetate extracts of VA was capable of inhibiting the growth of human breast cancer cells even at very low concentrations of 0.1 mg/ml to concentration of 1 mg/ml, the inhibition was as high as 98% for some fractions of the extract [47]

Cold water, hot water and ethanol extract were found to induce apoptosis against acute lymphoblastic leukemia (ALL) and acute myeloid leukemia (AML) from the patients with IC50 ranging between 5 to 10 μg/ml. Ethanol extract was found to be most effective against both ALL and AML when compared to cold and hot water extract [48. Petroleum ether/ ethyl acetate leaf extract also possessed cytotoxic effect towards human hepatoblastoma (HepG2) and urinary bladder carcinoma (ECV-304) cell lines [49]. These findings establish the usefulness of *V. amygdalina* Del. in managing breast cancer.

Bioactive peptides from the aqueous extract of the plant leaves (edotides) have been shown to be potent in managing cancer by its activity on mitogen activated protein kinases and signal transduction pathways [46, 50].

Vernoninia amgdalina leaf is a vegetable with several potentials in the prevention and treatment of various ailments associated with oxidative stress.

2.2. *Telfairia occidentalis* (T.O.)

Telfairia occidentalis Hook f. commonly called fluted pumpkin occurs in the forest zone of West and Central Africa, most frequently in Benin, Nigeria and Cameroon. It is a popular vegetable all over Nigeria. It has been suggested that it originated in south-east Nigeria and was distributed by the Igbos, who have cultivated this crop since time immemorial [51]. It is

a vigorous perennial vine, growing to 10m or more in length. The stems have branching tendrils and the leaves are divided into 3– 5 leaflets. The fruits are pale green, 3 – 10 kg in weight, strongly ribbed at maturity and up to 25cm in diameter. The seeds are 3– 5cm in diameter [52]. The leaf is consumed in different parts of the country because of the numerous nutritional and medicinal attributes ascribed to it. It has different traditional names; among Igbos, it is known as "Ugu", "iroko" or aporoko in Yoruba, ubong in Efik, umee in Urhobo and umeke in Edo [53]. Young succulent shoots and leaves are used as vegetables in the eastern part of Nigeria. The herbal preparation of the plant has been employed in the treatment of sudden attack of convulsion, gastrointestinal disorders, rmalaria and anaemia [54].Also the plant has agricultural and industrial importance in addition to its nutritional value [55].

Quite a number of researchers in the field of medical sciences have observed free radical scavenging ability and antioxidant property in *Telfairia occidentalis*. The darkish green leafy vegetable of *Telfairia occidentalis* and extracts (such as aqueous and ethanol extracts) from the leaves have been found to suppress or prevent the production of free radical and scavenge already produced free radical, lower lipid peroxidation status and elevates antioxidant enzymes (such as superoxide dismutase and Catalase) both in vitro and *in vivo* ([56,57-61,62]. They reported that extracts of this vegetable using various solvents were able to offer a chemopreventive and protective effects on oxidative stress induced serum and organs like kidney, liver and brain. Studies have shown that T.O. leaves are rich in antioxidants such as ascorbic acid and phenols [63, 64].

Specifically Oboh et al [57] in their study showed the antioxidant properties of T. O. by assessing their total phenolic content, reducing property and free radical scavenging properties against DPHH radical. From that study the aqueous extracts had a significantly higher total phenol content than the ethanolic extracts which clearly indicates that the phenols present in *Telfairia occidentalis* leaves are more water soluble than ethanol, consequently, the aqueous extracts could be a more potent antioxidant than the ethanolic extracts. this gives credit to the fact that aqueous extracts of the leaf is presently used in the management and prevention of anaemia and diabetes. This high phenol content in the aqueous extracts could have contributed to the prevention/ management of hemolytic anaemia [65] diabetes [66] which is associated with free radical damage.

Antioxidants may been classified into two separate groups: those that suppress the generation of reactive oxygen species and those that scavenge the reactive oxygen species generated[57] . Also in the same study it was observed that the aqueous extract had a significantly higher reducing power and higher free radical scavenging ability than the ethanolic extracts. The higher phenolic content in the aqueous extract would have accounted for the higher ability of the aqueous extract to reduce Fe (III) to Fe (II) in the FRAP test for reducing ability [67]. Also the chelating properties of phenols have been reported to have high reducing power [68] which clearly indicate that *Telfairia occidentalis* leaf antioxidant potentials will be more harness in its aqueous extraction than the ethanolic extraction and this is in accord with the form in which the plant is presently been used. Furthermore, the high reducing power and free radical scavenging ability of the extracts clearly indicate that

both extracts of *Telfairia occidentalis* could suppress the generation of free radical and scavenge free radical. Protocatechiuc acid (PRA) and caffeic acid was shown to be the main polyphenolic compound present in the leaves of T.O.[69]. Cafeic acid is a phenollic compound present in the plant kingdom [70]. It is known to have a large number of physiological activities including anti-inflammatory, anti allergic and anti tumour [71, 72, 73]. They also revealed in their study the high flavonoid content, total antioxidant content, lipid peroxidation inhibition, free scavenging activity towards hydroxyl radical and superoxide scavenging abilities of *Telfairia occidentalis* amongst other vegetables. Therefore the consumption of leaves of T O will provide adequate antioxidants capable of preventing diseases arising from oxidative stress thus promoting the general well being of an individual.

The hepatoprotective properties of polyphenol extracts on T O leaves on acetaminophen induced liver damage was observed [58]. It was demonstrated that the soluble free polyphenol had a higher protective effect on the liver than bound polyphenol in this vegetable. This agrees with previous studies where correlation was reported between antioxidant properties and total polyphenolic content of some commonly consumed vegetables and fruits [56, 57, 74, 75,] Free phenolics are more readily absorbed and thus exert beneficial bioactivities in early digestion. The significance of bound phytochemicals to human health is however not clear [75, 76] and Chu et al 2002.

Telfairia occidentalis leaves have been reported to also be protective against liver damage [76, 77]. The use of the leaves in folk medicine in Nigeria in the treatment of certain diseases in which the participation of reactive oxygen species have been implicated could be as a result of the antioxidant and free radical scavenging ability [62].

Oxidative stress which have been implicated in quite a number of diseases such as anaemia, malaria, diabetes cancer and so on have been reported to be relieved by antioxidants inherent in vegetables, fruits and other plants. It is to this end that Salama *et al* [78] reported that aqueous extract of *Telfairia occidentalis* leaves reduces blood sugar and increases haematological and reproductive indices in male rats. *T. occidentalis* actually caused significant increases in packed cell volume, haemoglobin concentration, red blood cell count and white blood cell count in addition to a significant decrease in blood glucose. The increase in the hematological indices observed in this study is consistent with the observations made when rats were fed with the diet preparation of the air-dried leaves of *T. occidentalis* for four weeks [79] This study has also shown for the first time that new blood cells would have started appearing in the circulation after the fifth day of treatment with *T. occidentalis* and the increase would become significant after the seventh day of treatment and beyond. This increase is due to the chemical composition of *Telfairia occidentalis* particularly the presence of the vitamin A and C which are well known antioxidants capable of scavenging free radicals [80]. Some of these constituents are well-established haemopoietic factors that have direct influence on the production of blood in the bone marrow. For instance, iron is a well known haemopoietic factor [81]. Also the amino acids derived from *T. occidentalis* could also be used for the synthesis of the globin chains of the haemoglobin and this could also contribute to the increase in haemoglobin concentration. The significant increase observed in this study is however inconsistent with the insignificant change in haematological parameters observed when birds

were fed with the dietary preparation of the sun-dried leaves of the plant [82]. The insignificant change observed with the sun-dried leaves might be due to the denaturing of the active ingredients especially proteins in the leaves during exposure to sunlight. In addition, the inconsistence may be an indication of a species variation in the responses to the effects of the plant. In the same study the leaves were observed to reduce blood sugar significantly, an indication of its hypoglycemic properties. This was confirmed in recent study on the comparative hypoglycemic properties of the ethanolic and aqueous extracts of leaves and seeds of this plant [83]. The hypoglycemic property is more in the leaves and was concluded to be better extracted with ethanol than water.

In the same way it was shown that this leave extract improve sperm motility, viability and counts generally improving sperm quality [78]. This is attributed to the actions of some of its active ingredients which have well documented spermatogenic activities. In this respect, studies have shown that nutritional therapies with zinc [84], vitamin C [85], vitamin E [86] and arginine [87] proved beneficial in treating male infertility. Therefore it may be very useful in the treatment and management of infertility especially that associated with reduction in sperm performance.

The antianaemic potentials of the aqueous extract of leaves of *Telfairia occidentalis* extracts against phenyl hydrazine-induced anaemia in rabbits was investigated [88]. Anaemia constitutes a serious health problem in many tropical countries because of the prevalence of malaria and other parasitic infections. In anaemia there is decreased level of circulating haemoglobin, less than 13 g dL^{-1} in male and 12 g dL^{-1} in females [89]. In the tropics, where malaria is endemic, between 10 to 20% of the population presents less than 10 g dL^{-1} of Haemoglobin [90]. Children are more vulnerable. The leaves are rich in iron and play a key role in the cure of anaemia, they are also noted for lactating properties and are in high demand for nursing mothers [91].

Elaboration of the therapeutic effect of *Telfairia occidentalis* on protein energy malnutrition-Induced liver damage was specifically emphasized in previous study [61]. The protein deficient diet caused a significant increase in hepatic malondialdehyde (MDA) level and the liver function enzymes alkaline phosphatase (ALP), alanine amino transferase (ALT) and aspartate amino transferase (AST) activities in the serum. It also caused a marked reduction in glutathione level, significant decrease in the antioxidant enzymes superoxide dismutase (SOD) and catalase (CAT) and significant damage to the hepatocytes. Recovery diets of protein alone and protein supplemented with *T. occidentalis* had significant effects on all the parameters. The MDA level and the serum liver function enzymes were significantly reduced while glutathione and antioxidant enzymes levels were markedly increased and a highly significant hepatocyte healing observed in the histology images.

2.3. OCIMUM

The genus ocimum is represented by over 50 species of herbs and shrubs in Africa. *Ocimum basilicum* and *Ocimum gratissimum* are known in Africa to manage different diseases. They belong to the family of plant known as Lamiaceae [92]. Local names of different species of

ocimum in various ethnic groups include *Efirin* (Yoruba), *neh-anwu* (Ibo), *ntion* (Efik) and *dai-doya ta gida* (Hausa). The leaves can be petiolate or sessile, often toothed at the margin. They are erected and have characteristic pleasant aroma due to their volatile oil [92]. *Ocimum gratissimum* leaf or the whole plant is known to be popular treatment remedy for diarrhoea [93]. The plant is rich in voltile oils, which contain up to 75 percent of thymol, the antimicrobial activity of which is well known. Infact, the antimicrobial activity of the water-saturated oil had been shown to be proportional to the thymol content [94].

Ocimum gratissimum is effective in the management of upper respiratory tract infection, diarrhoea, headache, skin disease, pneumonia, fever, and conjuctivities.[95]. Traditionally *Ocimum basilicum* (basil) has been used as a medicinal plant for various ailments, such as headaches, coughs, diarrhoea, constipation, warts, worms and kidney malfunction. It is also thought to be an antispasmodic, stomachicum, carminative, antimalarial, febrifuge and stimulant [96, 97]. Ethnobotanical surveys report the traditional utilization of basil as a veterinary medicinal plant as well. Basil oil, especially the camphor containing oil, has antibacterial properties. The vapour of boiling leaves is inhaled for nasal or bron-chial catarrh and colds. The leaves may be rubbed between the palms and sniffed for colds. It cures stomach- ache and constipation. The leaves are crushed and the juice is used as vermifuge. It is further used to repel mosquitoes and as a broom to sweep chicken house in order to get rid of fleas.

Reactive oxygen species (ROS) have been implicated in some of the disorders associated with the traditional uses of some vegetables, such as malaria, anaemia, gastrointentional tract disorders, diabetes mellitus and inflammatory injury. Hence this forms the basis for the investigation of the antioxidant properties of some of these vegetables in order to validate the acclaimed traditional use.

A comparative study on the antioxidant properties of two Nigerian species of Ocimum showed that the methanolic extract of *Occimum gratissimum* posses a higher polyphenolic, flavonoid comoponent and free radical scavenging activities when compared to the methanolic extract of *O. basillicum* [98]. Thus this may be reason behind wider utilization of *O. gratissimum* in Nigerian folk medicine than *O. basillicum.*

Basil has been shown to contain *flavonoid* glycosides (0.6–1.1%) and flavonoid aglycones. A flavone, xanthomicrol (5, 4'-dihydroxy-6, 7, 8-trimethoxyflavone) was isolated from the leaves of a Nigerian *O.basilicum* [99, 100]. Basil herb *(O.basilicum)* contains apart from essential oil and flavonoids also tannins and polyphenols (2.2–2.3%)[99, 100].

The phytochemical and antioxidant activity of methanolic and aqueous extract of *Ocimum gratissimum* (OG) were investigated and the results showed the presence of flavonoids, steroids, cardiac glycosides, tannins, phlobatannins in both extract [101]. The methanoilic extract of OG was shown to exhbit a higher DPHH scavenging activity (84.6%) at 250 μg/ml and a reductive potential of 0.77 at 100 μg/ml comparable with those of gallic acid, 91.4% at 250 μg/ml and ascorbic acid, 0.79 at 60 μg/ml as standards for DPPH scavenging activity and reductive potential, respectively. Thus OG - leaf extracts possess antioxidant potential probably because of its phytochemical constituents which has also been reported in other

studies [102,103-104]). Also the hepatoprotective effect of extract of leaf of OG was also reported [105].

The methanolic extract of leaf of OG was also shown to be capable of scavenging the free radiacal 2,2-diphenyl-1-picrylhydrazyl (DPPH.) radical, superoxide anion radical ($O2^{-}$), hydroxyl radical (.OH), nitric oxide radicals (NO.), as well as inhibiing lipid peroxidation, using appropriate assay systems compared to natural and synthetic antioxidants.

The analgesic and hepatoprotective activity of the methanolic extract of *Ocimum gratissimum* (L.) leaves in carbon tetrachloride hepatoxic - albino rats was reported. A significant decrease in the liver enzmes were observed in the the hepatoxic albino rats after treatment with the methanolic extract of OG thus showing its protective effect on the damaged liver [106].

2.4. *Adansonia digitata*

Baobab (*Adansonia Digitata* L) is a tree found widely throughout Africa and known locally in African countries as the "tree of life" due to its ability to sustain life owing to its water holding capacity, as well as its many traditional medicinal and nutritional uses [107]. The baobab tree is an important food, water and shelter source in many African countries [108].). *Adansonia digitata* is commonnly called *Kukah* by the Hausa of Northern Nigeria, Niger *konian*, Kenyans *Mwambom*, Mali *sira*, Senegal, *gou*i ([109]). *Adansonia digitata* is one of eight species of the *Adansonia* genus, and its name originates from the fact that the oblong leaves of the tree, often formed in groups of five, look like the fingers or digits of the human hand. It is a deciduous tree which has four growth phases and produces a fruit consisting of a yellowish-white pulp which has a floury texture and numerous hard, round seeds, enclosed in a tough shell [107].

The leaves of the baobab tree are a staple for many populations in Africa, especially the central region of the continent [110, 111]. During the rainy season when the baobab leaves are tender, the leaf is harvested fresh. During the last month of the rainy season, leaves are harvested in great abundance and are dried for domestic use and for marketing during the dry season. The leaves are typically sun-dried and either stored as whole leaved or pounded and sieved into a fine powder [112]. The Powdered leaves are used as a tonic and an anti-asthmatic and known to have antihistamine and anti-tension properties. The leaves are also used to treat insect bites, guinea worm and internal pains, dysentery, diseases of the urinary tract, opthalmia and otitis ([109].). In Indian medicine, powdered leaves are similarly used to check excessive perspiration ([109].). Baobab leaves are used medicinally as a diaphoretic, an astringent, an expectorant and as a prophylactic against fever [113].

Baobab leaves have been investigated in an attempt to identify the potential bioactives associated with this part of the plant [12,114,115-116,117. Certain bioactive compounds may be responsible for the treatment of certain ailments, as well as containing properties that can be beneficial to overall health. Examples of such bioactive compounds include tannins, phlorotannins, terpenoids, glycosides, saponins and terpenoids [116] as well as antioxidants

including flavonoids and polyphenols [114]. The chemical profile of the methanolic and aqueous extracts of the leaves of the plant was also investigated [118]. They reported the presence of glycosides, phytosterols, saponins, protein and amino acid, phenolic compounds and tannins, gums, mucilage and flavanoids. Only few authors have investigated the vitamin A content of baobab leaves. Scheuring *et al*. [119] found that the simple practice of drying baobab leaves in the shade protects against deterioration of provitamin A. The selection of small leaves further increased provitamin A by 20%. The combination of small leaves and shade drying enabled the retention of the provitamin content up to 27 μg retinol equivalent per gram of dried leaf powder. Other authors mention the carotenoid content of baobab leaves [120,121].

Literature review revealed a great variation in reported values of nutrient contents of baobab part. According to Chadare *et al* [122] the causes of these variations are not well known, however they made several assumptions. The variation may be due to the quality of the sample, the provenance of the sample, the age of the sample, the treatment before analysis, the storage conditions, the processing methods, a probable genetic variation, and the soil structure and its chemical composition.

It is a known fact that the consumption of antioxidant-rich foods can contribute to the prevention of oxidation in the human cell, hence of some diseases. In addition to the general chemical composition of baobab pulp and leaves discussed previously, the antioxidant content of the aqueous extract of wild plants including *Adasonia digitata* was investigated [123]. They showed that baobab leaves have an antioxidant content of 7.7 μmol/g dw expressed as Trolox equivalents. This result is almost 1000 times lower than composition and nutritional value of baobab foods the one reported by Vertuani *et al.* (2002), who found that the water-soluble antioxidant capacity of dry baobab leaves was 6.4 mmol Trolox equivalent/g. These antioxidant activities were measured in fresh raw material and the effect of cooking and storage is not well known. Only Tarwadi and Agte [125] reported the antioxidative activity of some fruits and root vegetables before and after cooking. The antioxidant activity was measured as the inhibition of thiobarbituric acid reactive substances (TBARS), superoxide radical scavenging activity (SOSA), and ferrous iron chelating ability (FICA). They reported that there were significant cooking losses for each of the assessed antioxidant parameters.

A. digitata leaves, fruit-pulp and seeds have earlier been reported to show antiviral activity against influenza virus, herpes simplex virus and respiratory syncytial virus and polio [117]. Chemical analyses have reported the presence of various potentially bioactive ingredients including triterpenoids, flavonoids and phenolic compounds [122]. These bioactive compounds especially flavonoids and phenolic may be responsible for the nutritive and medicinal properties of this vegetable.

Karumi *et al* [125] also reported the gastro protective effect of *Adansonia digitata* leaf on ethanol induced ulceration. This study elucidated a significant dose- dependent increase both in preventive ratio and percentage ulcer reduction after pretreatment with *Adansonia digitata* leaves. Ethanol is an established ulcerogen especially in empty stomach [126]. The

ulcerogenicity of ethanol is due to intracellular oxidative stress producing mitochondrial permeability, transition and mitochondrial depolarization which results to the death of cells in gastric mucosa [126,127]. This is because of its congestive inflammation and tissue injury. It is a known fact that flavonoids and anti-oxidant (Vit A, E and C) present in this plant has protective role. This view is supported by the fact that gastric mucosa is known to have certain antioxidant activity thereby reducing mucosal damage mediated by free radicals[128] which in turn attack cell membrane causing a lipid derived free radicals such as conjugated diene and lipid hydroperoxides which are extremely reactive and unstable. This study corroborate with previous report on the anti-ulcerative properties of the aqueous extract of *Adasonia digitata* leaves against ethanol induced ulceration in rats [129]. Although the precise mechanism of action of *A. digitata* is not clear, it was proposed that the gastoprotective role of this vegetable extract may be partly due to its high content of flavonoids and antioxidant [130] which are well known compounds that prevent and combat the formation of reactive oxygen species. Another possible mechanism is the fact that the leaves being an astringent may have precipitated microproteins on the site of ulcer thereby forming an impervious protective pellicle over the lining to prevent absorption of toxic substance and resist the attack of proteolytic enzymes [131].

2.5. *Corchorus olitorius*

*Corchorus olitorius (*Linn). is a leafy vegetable that belongs to the family tiliaceae and commonly called jute mallow in English and "ewedu" in the south western Nigeria. It is an animal herb with a slender stem and an important green leafy vegetable in many tropical area including Egypt, Sudan, India, Bangladesh, in tropical Asia such as Philippine and Malaysia, as well as in tropical Africa, Japan, the Caribbean and Cyprus [132]. The plant is widely grown in the tropics for the viscosity of its leaves. The leaves (either fresh or dried) are cooked into a thick viscous soup or added to stew or soup and are rich sources of vitamin and minerals [133]. Nutritionally, *C. olitorius* on the average contain 85-87 g H_2O, 0.7 g oil, 5 gcarbohydrate, 1.5 g fiber 250-266 mg Ca, 4.8 mg Fe, 1.5 mg 300010 vitamin A, 0.1 mg thiamine, 0.3 mg riboflavin, 1.5 mg nicotinamide, and 53-100 mg ascorbic acid per 100 g [134]

In West African countries including Ghana, Nigeria and Sierra Leone, the vegetable is cultivated for the stem bark which is used in the production of fibre (Jute) and for its mucilaginous leaves which are also used as food vegetable [135] The leaf extract of the plant is also employed in folklore medicine in the treatment of gonorrhea, pain, fever and tumour [136]. It is reportedly consumed as healthy, vegetable in Japan because of its rich contents of carotenoids, vitamin B_1, B_2, C and E, and minerals [137]. Its leaves and roots are eaten as herbal medicine in South East Asia [136]. In some part of Nigeria leaves' decoction used for treating iron deficiency, folic acid deficiency, as well as treatment of anaemia. Leaves also act as blood purifier [138] and the leaf twigs is used against heart troubles [139] while cold leaf infusion is taken to restore appetite and strength, leaves used for ascites, pains, piles, tumours, gonorrhoea and fever [140]

The hepatoprotective effect of the ethanolic etract of ewedu amongst other vegetables against CCl_4 induced hepatic damage in rats was studied [141]. Ethanolic extracts of *Corchorus olitorious* was shown to produce a significant hepatoprotective effect by decreasing serum and liver levels of ALT, AST, and total protein at dose of 250 and 500mgkg^{-1} in carbon tetrachloride induced hepatotoxic rats [141]. Their result also shows a significant inhibition of lipid peroxidation as illustrated by the decreased value on the MDA Values.

The phenolic antioxidants in the leaves of *Corchorus olitorious* was identified to include phenolic [5-caffeoylquinic acid (chlorogenic acid), 3, 5-dicaffeoylquinic acid, quercetin 3-galactoside, quercetin 3-glucoside, quercetin 3-(6-malonylglucoside), and quercetin 3-(6-malonylgalactoside) (tentative)] were identified from the leaves of *Corchorus olitorious L.* by NMR and FAB-MS. The contents of these phenolic compounds, ascorbic acid, and alpha-tocopherol in *C. olitorius* leaves were determined, and their antioxidative activities were measured using the radical generator-initiated peroxidation of linoleic acid. The results obtained showed that 5-caffeoylquinic acid was a predominant phenolic antioxidant in C. olitorius leaves (phenolic antioxidants from the leaves of *Corchorus olitorius L.* None of these phenolic compounds was detected in recent study on the chemical composition and invitro antioxidant properties of some selected vegetables [69]. Only caffeic acid acid was present to significance in the vegetable by the GC-MS analysis. Caffeic acid is a phenolic compound widely present among many plants which has been studied extensively and known to share a spectrum of physiological activities including anti-inflammatory anti-allergic and anti tumour [142-144] They further investigated the peroxidation inhibitory capacity of corchorus oliotorius among other vegetables and they resolved that though all vegetables evaluated were able to inhibit lipid peroxidation, the consumption of the vegetables especially *Vernonia amygdalina* and *Corchorus olitorious* may afford a better cytoprotective effects. Further results from these study showed that the ethanolic extract of *Corchorus olitorious* and other evaluated vegetables has high superoxide and hydrogen peroxide scavenging ability of *Corchorus olitorious* which could possibly be due to the presence of caffeic acid, flavonoids and in general the high total antioxidants.

Oboh *et al* [145] carried out a comparative study of the antioxidant properties of hydrophilic extract (HE) and lipophilic extract (LE) constituents of the *Corchorious olitorius*. HE and LE of the leaf were prepared using water and hexane, respectively and their antioxidant properties were determined. HE showed a significantly higher (1,1-diphenyl-2-picrylhydrazyl radical-scavenging ability ,reducing power ,trolox equivalent antioxidant capacity than LE. conversely, LE showed a significantly higher hydroxyl scavenging activity than HE while there was no significant difference in their Fe(II) chelating ability. The higher 1,1-diphenyl-2-picrylhydrazyl radical-scavenging ability, reducing power and trolox equivalent antioxidant capacity of the hydrophilic extract may be due to its significantly higher total phenol (630.8 mg/100 g), total flavonoid (227.8 mg/100 g) and non-flavonoid polyphenols (403.0 mg/100 g), and its high ascorbic acid content (32.6 mg/100 g). While the higher OH. Scavenging ability of LE may be due to its high total carotenoid content (42.5 mg/100 g). Therefore, the synergistic antioxidant activities of the hydrophilic and lipophilic constituents may contribute to the medicinal properties of *C. olitorius* leaf [145].

Further study illustrated the the protective effect of aqueous extract of *Corchorus olitorius* leaves (AECO) against sodium arsenite-induced toxicity in experimental rats [146]. A significant inhibition of hepatic and renal antioxidant enzymes such as superoxide dismutase, catalase, glutathione-S-transferase, and glutathione peroxidase and glutathione reductase were observed. The level of reduced glutathione decreased while the levels of oxidized glutathione and thiobarbituric acid reactive substances in the selected tissues were increased following arsenic intoxication. Treatment with AECO at doses of 50 and 100mg/kg body weight p.o. for 15days after arsenic intoxication significantly improved hepatic and renal antioxidant markers in a dose dependant manner. AECO treatment also significantly reduced the arsenic-induced DNA fragmentation of hepatic and renal tissues. Histological studies on the ultrastructural changes of liver and kidney supported the protective activity of the AECO [146]. Thus aqueous extract of *Corchorus olitorius* leaves is significant in protecting animals from arsenic induced hepatic and renal toxicity.

2.6. *Gongronema latifolium*

Gongronema latifolium belongs to the family of Asclepiadaceae family. The plant common name is amaranth globe. The parts commonly used are leaves, stem and root. The origin of the plant is traced to Nigeria in West Africa. *Gongronema latifolium is* called *madumaro* by Yoruba ethnic group in Nigeria commonly called 'utazi' by the Ibo of south eastern part if Nigeria. It is a tropical rainforest plant primarily used as spice and vegetable in traditional folk medicine [147,148]. They are sharp-bitter, sweet and widely used as a leafy vegetable and as a spice for sauces, soups and salads. *Gongronema latifolium* is widely used in West Africa for medicinal and nutritional purposes. An infusion of the aerial parts is taken to treat cough, intestinal worms, dysentery, dyspepsia and malaria. It is also taken as a tonic to treat loss of appetite. In Sierra Leone an infusion or decoction of the stems with lime juice is taken as a purge to treat colic and stomach-ache. In Senegal and Ghana the leaves are rubbed on the joints of small children to help them walk. The boiled fruits in soup are eaten as a laxative. In Nigeria a leafy stem infusion is taken as a cleansing purge by Muslims during Ramadan. A decoction of leaves or leafy stems is commonly taken to treat diabetes and high blood pressure. The latex is applied to teeth affected by caries. It is also taken for controlling weight gain in lactating women and overall health management. Asthma patients chew fresh leaves to relieve wheezing. A cold maceration of the roots is also taken as a remedy for asthma [149]. A decoction of the roots, combined with other plant species, is taken to treat sickle cell anaemia. A maceration of the leaves in alcohol is taken to treat bilharzia, viral hepatitis and as a general antimicrobial agent [150].The leaves are used to spice locally brewed beer. In Sierra Leone the pliable stems are used as chew sticks. The bark contains much latex and has been tested for exploitation.

Phytochemical screening of Gongronema latifolium vegetable showed the presence of alkaloids, tannnis, glycosides, polyphenols, saponins and flavonoids [151, 152]. Other chemical analyses on the leaves revealed several 17β-marsdenin derivatives (pregnane glycosides) as well as β-sitosterol, lupenyl cinnamate, lupenyl acetate, lupeol, essential oils

and saponins. The essential oil from the leaves contains as main components linalool (19.5%), (E)-phytol (15.3%) and aromadendrene hydrate (9.8%) [151, 153-154].

Hepatoxicity induced by carbon tetrachloride in albino rats was found to be relieved by the ethanolic extract of *Gongronema latifolium* GLE [155]. Carbon tetrachloride induction in the rats resulted in hepatic injuries hence the marker of liver damage AST and ALT was reported to be significantly high in carbon tetrachloride induced rats however ALP was not siginificantly increased. It is well documented from histological studies on the liver that necrosis in the centrilobular zone is a major cause of carbon tetrachloride induced acute liver injury [156]. Treatment with the ethanol extract of *Gongronema latifolium* was shown to reduce the AST and ALT concentration significantly. Reduced levels of ALT and AST in rats treated with the extract could be attributed to the ability of the GLE to prevent the metabolism of carbon tetrachloride into more toxic metabolite and minimized the production of free radicals and also boost the activities of the scavengers of free radicals [157] thus minimizing hepatocellular injury produced. No evident increase or decrease in the level of ALP was observed. Absence of any concomitant increase of decrease on the ALP levels, under experimental conditions, was attributed to the fact that the single dose, intraperitioneal injection of the carbon tetrachloride at the pre-stated concentration/dosage, may not have caused any significant ($P<0.05$) billiary tract obstruction or disease [158] while causing acute hepatocellular injury [159]. Also the protective role of *Gongronema latifolium* in acetaminophen induced hepatic toxicity in Wistar rats was elucidated by [160]. Serum enzyme activities such as AST, ALTand ALP were increased following acetaminophen and caffeine administration in their study. The increase in liver enzymes following acetaminophen administration has earlier been reported by [39,161]. It has been reported that acetaminophen could be bioactivated enzymatically by cytochrome P4502EI in both liver and kidney. The metabolic activation by reactive intermediate N-acetyl parabenzoquinoneimine is believed to play an important role in acetaminophen mediated toxicity [162]. The proinflammatory cytokines such as tumor necrosis factor (TNF-a) and interleukin-la, that are released in response to acetaminophen intoxication are thought to be responsible for some pathological manifestations of acetaminophen induced toxicity [161]. However, the simultaneous administration of acetaminophen, caffeine and extract of *G. latifolium* significantly lowered AST, ALT and ALP concentrations when compared with those that received acetaminophen only and acetaminophen and caffeine. This is in line with the work of [155, 163].The mechanism by which *G. latifolium* lowered liver enzymes may be attributed to their ability to maintain liver cell integrity. It can therefore be concluded that acetaminophen offer protection against acetaminophen and caffeine induced hepatoxicity.

Earlier the oral administration of aqueous and ethanolic extract of *Gonogronema latifolium* was shown to possess' antidiabetic properties on streptozotocin-induced diabetic [147]. Also both extracts were shown to significantly increase the activity of superoxide dismutase and the level of reduced glutathione. The aqueous extract further increased the activity of glutathione reductase while the ethanolic extract caused a significant increase in the activity of glutathione peroxidase and glucose-6-phosphate dehydrogenase and a significant decrease in lipid peroxidation.

Gongronema Latifolium has also been shown to possess antiplasmodal activity; this supports the traditional use of the leaf extract of the plant for local treatment of malaria. Akuodor [164] and his team in their review stated that *Gongronema Latifolium* (madumaro) is used in South Eastern Nigeria to treat various ailments such as cough, loss of appetite, malaria and stomach disorders.The liquor usually obtained after the plant is sliced and boiled with lime juice or infused with water over three days is usually taken as a purge for colic and stomach pains. Various parts of the plant, particularly the stems and leaves are used as chewing sticks or liquor in Sierra Leone. It is also used to treat symptoms related to worm infections. *Gongronema Latifolium* is good for maintaining healthy blood glucose level and has antibacterial activity.

It was also reported that the ethanol extract of *Gongronema Latifolium* leaves when evaluated were found to possess anti-ulcer, analgesic and antipyretic activities. The plant enjoys reputation as a remedy for inflammation, bacteria, ulcer, malaria, diabetes and analgesic [164].

Other researches show its antimalarial effect, anti-inflammatory properties, and antisickling properties [165, 166]. This vegetable is reservoir of many antioxidants capable of preventing and treating different diseases.

2.7. *Gnetnum africanum*

Gnetum africanum is one of the most popular leafy vegetable in Nigeria which is gaining popularity as a delicious food leaf in other African countries such as Cameroon, Gabon, Congo and Angola [167]. It is called with different Local names: 'fumbwa' (DRCongo), 'okok', 'eru' (Cameroon), 'afang', 'okazi' (Nigeria). G. africanum, a lone genus belonging to the family Gnataceae is a dioecious wild undestorey liana that grows on trees in the humid forest of Africa [168].

The leaves of *G africanum* are elliptic in shape and are lined with reticulate veins comparable to those of a dicotyledonous angiosperm [169]. Its leaves are eaten as a vegetable, either raw or finely chopped and cooked; they are also widely used as an ingredient in soups and stews and are much in demand for their nutritional and therapeutic properties. It is traditionally used in the treatment of enlarged spleen, sore throat and as as a cathartic [170]. It is also used to relief nausea and neutralizes poison in Congo as well as been applied externally to manage boils, warts and used to reduce child birth pain. The leaves of *A. Gnetum* species are also used as a disinfectant for wounds treat heamorrhoid and increase blood production in the human organism [171].

In Nigeria, the leaf of *G. africanum* is used in the treatment of an enlarged spleen, sore throats and as a cathartic [171]. In Ubangi (DR Congo), it is used to treat nausea and is considered to be an antidote to some forms of poison [171. In Congo-Brazzaville, the leaves of both species are used as a dressing for warts and boils and a tisane of the cut-up stem is taken to reduce the pain of childbirth [172].*Gnetum africanum* is also reported to be used for medicinal purposes in Mozambique [173].

The leaves have very high nutritional value and constitute an important source of protein, essential amino acids and mineral elements [168]. Flavonoids, phenols anthocyanins have been shown to be present in the leaves of *Gnetum africanum* [174]. As is already know flavonoids is a class of secondary plant phenolics with powerful antioxidant properties. Phenols are regarded as the most important oxidative components of plants, hence correlation between the concentration of total plant phenolics and total antioxidant capacities have been reported [175]. The presence of these phytochemicals agrees with previous work of Iweala et al [176] who elucidated the presence of phenolic substances, flavonoids, anthocyanidins, phytosterols, tannins, saponins, alkaloids, glycosides, cyanogenic and cardiac glycosides ingnetum africanum leaves. Long term feeding of *Gnetum africanum* supplemented diet caused significant increase in weight, haemoglobin and white blood cells [176]. Glutathione s transferase and superoxide dismutase where increased significantly while lipid peroxidation and serum protein was reduced significantly with supplementation of Gnetum africanum supplemented diet. The gain in weight was explained o be due to the presence of high quality nutrient present in this leafy vegetable while reduction in protein may be a consequence of indigestibility and unavalaibilty of protein content of *Gnetum africanum*. The presence of invitro antioxidants lile flavonoids and phenolic substance was reported to be responsible for the decrease in lipid peroxidation and increase in GST and SOD as well as increase in haemoglobin and white blood cells [176]. Also a recent study on the biochemical and histological changes in paracetamol induced hepatoxic rats showed that consumption of *Gnetum africanum* supplemented diet reduced liver necrosis caused by paracetamol induction [177]. They also reported that lipid peroxidation was significantly reduced in the diet supplemented group. Although the precise mechanism for this protective role was not reported, it may be associated to presence of flavonoids and phenolic compounds in the vegetable. In a more recent study [174] as earlier reported also evaluated the invitro antioxidant properties of the methanolic extract of two leafy vegetables telfaira occidenatalis and *Gnetum africanum*. They revealed that both vegetable extracts had strong DPHH radical and hydroxyl radical scavenging ractivities compared to the water soluble natural antioxidant ascorbic acid. Howevever *Telfaira occidentalis* extract was concluded to posses more scavenging activities than *Gnetum africanum*. The potent antioxidant activity of the two methanolic extracts might result from their high content of polyphenolic compound.

3. Antioxidant properties of selected fruits in African

Africa is blessed with several varieties of fruits which are either consumed for their nutrients or for their medicinal values. They are known to be rich with antioxidants that help in lowering incidence of degenerative diseases such as cancer, arthritis, arteriosclerosis, heart disease, inflammation, brain dysfunction and acceleration of the ageing process [6,178,179]. Antioxidants are substances which when present at low concentration are capable of preventing or delaying oxidative damage of lipids, proteins and nucleic acids by reactive oxygen species. These reactive oxygen species include reactive free radicals such as superoxide, hydroxyl, peroxyl, alkoxyl and non- radicals such as hydrogen peroxide,

hypochlorous, etc. They scavenge radicals by inhibiting initiation and breaking chain propagation or suppressing formation of free radicals by binding to the metal ions, reducing hydrogen peroxide, and quenching superoxide and singlet oxygen [180]. The most abundant antioxidants in fruits are polyphenols, Vitamin C, Vitamins A, B and E while carotenoids are present to a lesser extent in some fruits. These polyphenols, most of which are flavonoids, are present mainly in ester and glycoside forms [181]. The defensive effects of the natural antioxidants in fruits and vegetables are related to the three major groups: vitamins, especially vitamin C; phenolics; and carotenoids, especially β-carotene [182]. Vitamin C and phenolics are known as hydrophilic antioxidants, while carotenoids are known as lipophilic antioxidants. The antioxidant properties of a number of tropical fruits have been investigated on an individual basis using different analytical methods [183-185].

3.1. *Psidium guajava L.*

One of the most gregarious of fruit trees, the guava, *Psidium guajava* L belongs to the myrtle family (Myrtaceae), is almost universally known by its common English name or its equivalent in other languages. In Africa the names are: *gwaabaa* (Hausa); *woba* (Efik); *ugwoba* (Igbo); *guafa* (Yoruba) *ugwaba* in Efik [186]. Guava fruit, usually 4 to 12 centimetres (1.6 to 4.7 in) long, are round or oval depending on the species [187]. The outer skin may be rough, often with a bitter taste, or soft and sweet. Varying between species, the skin can be any thickness, is usually green before maturity, but becomes yellow, maroon, or green when ripe. Guava fruit generally have a pronounced and typical fragrance, similar to lemon rind but less sharp. Guava pulp may be sweet or sour, tasting something between pear and strawberry, off-white ("white" guavas) to deep pink ("red" guavas), with the seeds in the central pulp of variable number and hardness, depending on species.

Guava is a good source of minerals like iron, calcium, and phosphorus as well as many vitamins like ascorbic acid, pantothenic acid, vitamin A, carotenoids such as B- carotene and lycopene, and niacin [188]. Single common guava (P. guajava) fruit contains about four times the amount of vitamin C as an orange [189]. The fruit has also been shown to contain saponin combined with oleanolic acid. Morin-3-O-α-L-lyxopyranoside and morin-3-O-α-L-arabopyranoside and flavonoids, phenolic compounds such as ellagic acid, anthocyanin, guaijavarin, and quercetin are also reported [189]. chemical analysis of guava plant extract have revealed the presence of anti-microbial compounds [190], tannins, phenol triterpenes, flavonoids, guajivolic acid, guajavanoic acid, linolenic acid, linoleic acid, guavacoumaric acid, galaturonic acid, asphaltic acid, benzaldehyde, essential oils, saponins, carofenoid, cectin, fibre ,fatty acids and a high content of vitamins C and A in its fruit [191].

The hydrophilic and lipophilic antioxidant properties of guava fruits were reported by Thaipong [192]. They concluded from their investigation that both white and pink flesh guavas fruits showed high hydrophilic antioxidant activity and compounds for phenolic and vitamin C indicated that regular consumption of guava might be beneficial to health. Also hydrophilic antioxidant activity, the major activity, had high correlations with both total phenolic and vitamin C indicating that the use of the total phenolic or vitamin C content to determine antioxidant activity level in guava fruit was feasible. Phenolic and

vitamin C are the major contributors to the antioxidant activity of guava fruits, while the contribution of carotenoid is negligible.

A comparative study of the antioxidant properties of several tropical fruits showed that guava possess primary antioxidant potential, as measured by scavenging DPPH and iron (III) reducing assays [193]. Primary antioxidants scavenge radicals to inhibit chain initiation and break chain propagations. This characteristic of guava is attributed to its high total phenolic compounds. This result is in agreement with the report of a study which enumerated the antioxidant activity of guava fruits [194] thus the fruit of guava can be harnessed either for protective or preventive roles against diseases arising from oxidative stress

3.2. *Carica papaya*

The papaya is the fruit of *Carica papaya* which belongs to the genus Carica in the myrtle family (Caricaceae). The papaya is one of native plants of Central America but is wide spread throughout tropical Africa. It is a berry developing from syncarpous superior ovary with parietal plancentation [195]. It is popularly called pawpaw. Pawpaw fruit is one of the most nutritional fruits grown and consumed in Africa. A green papaya fruit has been reported to provides 26 calories, 92.1 g H2O, 1.0 g protein, 0.1 g fat, 6.2 g total carbohydrate, 0.9 g fiber and 0.6 g ash{ [196]. USDA National Nutrient database recorded an orange-freshed papaya (per 100 g) contained 39 calories, 88.8 g H2O, 0.61 g protein, 0.14 g fat, 9.81 g total carbohydrate, 1.8 g fiber, 0.61 g ash. Additionally, Oyoyede [197] tested the chemical profile of unripe pulp of *carica papaya* and reported papaya fruit was very rich in carbohydrate (42.28% starch, 15.15% sugar) but low levels of fat. Papaya fruit also contains high levels of vitamin C (51.2 mg/100g), vitamin A precursors including β-carotene (232.3 μg/100g), and β-cryptoxanthin (594.3 μg/100g), as well as magnesium (19.2-32.7 mg/100g), which has been reported by Wall [198] Papaya fruit also contains papain which is a major component of papaya latex and widely applied for meat tenderisation.In recent years, papain and other endopeptidases have been proven to have several medical benefits, such as defibrinating wounds and treatment of edemas [199]. In some African countries, such as Gambia, tropical papaya is used to treat paediatric burns due to its proteolytic enzymes. Exception of papain, other endopeptidases, such as leukopapain and chymopapain, is also able to facilitate wound cleaning, promoting growth and improving the quality of the scar. Some physical behavious (such as color and size) of papaya fruit are various due to various cultivars.

Though *C. papaya* is an edible and flavorful fruit, it has been used throughout Africa for its medicinal benefits since it was introduced from the Americas. *C. papaya* has been used as treatment for numerous maladies, ranging from gastrointestinal disorders to asthma and sexually transmitted diseases. Perhaps the most common use of *C. papaya* is that of its been an antihelmintic. Often, the plant is boiled along with herbal adjuvants in order to expel worms [200]. A decoction made from the seeds of *C. papaya* has been used to much the same effect. The leaves have also been used in infusions to treat internal parasites [201].

Along with its use as an antihelmintic, *C. papaya* has been used to treat numerous gastrointestinal disorders. The whole fruit of *C. papaya* has also been boiled and used as an infusion in order to treat stomach ulcers In Madagascar, a tea made of from *C. papaya* leaves has also been used in order to treat gastric ulcers as well as general gastric discomfort [202]. In the Congolese region of Africa, a decoction made of the ripe seeds is said to be a very effective treatment of dysentery [203]. *C. papaya* is also thought to be effective in treatment of malaria. Along with the leaves of *Azadirachta indica*, *C. papaya* has been used as a steam treatment for malaria [201]. The fruit of *C. papaya* has also been used as a popular hepatoprotective agent. In cases of jaundice and hepatitis, immature fruit is either eaten or used in a decoction [200]. Most studies reported that papaya fruits and its leaves had high antioxidant capacity due to their high contents of vitamin B (in leaves), vitamin C, E (in fruits), and carotenoids [193, 203,204].

Recently Oloyede *et al* [205] reported the antioxidative properties of ethyl acetate fraction of unripe pulp of carica papaya in mice. Quercetin and β-sitosterol were isolated from the methanolic extract and later liquid-liquid extract of unripe carica papaya fruits using soxhlet apparatus. They further investigated the invitro antioxidant properties of this fruit in mice and the result showed a significant increase ($p<0.05$) in the activities of Gluthaione reductase, Glutathione peroxidase, Gluthathione, and Glucose-6-phosphate dehydrogenase with a slight reduction in catalase activity in the ethyl acetate fraction in the liver. On the other hand No significant change in activities of GR, GST and CAT were observed in groups of animals administered ethyl acetate (100mg/kg) or Aqueous extract when compared to control that received distilled water only, but renal GPx activity decreased following administration of ethyl acetate fraction. It is likely that quercetin and β-sitosterol may be responsible for the antioxidant potential demonstrated by the ethyl acetate fraction from unripe fruit. Therefore it was suggested that carica papaya unripe fruit may be useful in the management of diseases such as diabetes, sickle cell anaemia and cardiovascular diseases where free radicals are often generated

3.3. *Citrullus lanatus*

Watermelon (*Citrullus lanatus*) which belong to the family of is a vine-like flowering plant originally from southern Africa [206] . The watermelon fruits loosely considered a type of melon has a smooth exterior rind(green, yellow and sometimes white) and a juicy, sweet interior flesh usually deep red to pink but sometimes orange, yellow and even green if not ripe. [206].water melon rinds are also edibles but most people avoid eating them due their unpleasant flavor.

C. lanatus is an annual herb with long (up to 10 m) stems lying or creeping on the ground, with curly tendrils. Leaves are 5-20 by 3-19 cm, and hairy, usually deeply palmate with 3-5 lobes, on 2-19 cm long petioles. Fruits vary considerably in morphology, size range from about 7cm in diameter to over 20cm. In addition, they vary in colour from pale yellow or light green (wild form) to dark green (cultivars), and with or without stripes; the pulp varies from yellow or green (wild forms) to dark red (cultivars). The flesh amounts to about 65% of

the whole fruit, and of this 95% is water. The plant has become naturalized in many drier parts of West Africa [207, 208].

Water melon fruit is a good source of, amino acid citrulline, vitamin A, vitamin C, the antioxidant lycopene, Beta carotene and potassium. Cucurbitacin the bitter principle in some species has diuretic and purgative properties. The fruit has but few medicinal uses in West Africa; Bitter forms are used in Senegal as a drastic purge and are considered poisonous [209]. Some other ethno-medicinal uses of the fruit include diuretic, purgative, remedy for urinary conditions suggestive of gravel and stone in the bladder, gonorrhoea and leucorrhoea in women [210,211].

lycopene and citrulline have been shown to be present in this fruit and are helpful in preventing some chronic diseases[212]. The amount of lycopene in watermelon is highly variable, but generally exceeds that of tomato.Citrulline is present in all parts of the fruit [213]. Lycopene was found to be relatively stable in fresh cut watermelon, and could increase slightly in whole fruit held at room temperature [214]. Seedless watermelon generally had more lycopene than seeded types, and lycopene was present in red fleshed fruit, with small amounts in orange fleshed watermelon, and none in yellow fleshed types. Lycopene has been extensively studied for its antioxidant and cancer-preventing properties, in contrast to many other food phytonutrients, whose effects have only been studied in animals, lycopene has been repeatedly studied in humans and found to be protective against a growing list of cancers, these cancers now include prostate cancer, breast cancer, endometrial cancer, lung cancer and colorectal cancers [215,216]. The antioxidant function of lycopene lies in its ability to help protect cells and other structures in the body from oxygen damage. Protection of DNA (our genetic material) inside of white blood cells has also been shown to be an antioxidant role of lycopene [217]. The amino acid citrulline in watermelon is a known stimulator of nitric oxide. Nitric oxide is known to relax and expand blood vessels much like the erectilw dysfunction drug Viagra and may increase libido [218]. The health benefit of watermelon fruit is associated with its status as a powerful antioxidants found in vit A, lycopene and beta carotene. These helps to neutralize free radicals hence can be use in the the prevention of diseases associated with oxidative stress such as diabetes, asthma, artherosclerosis and so on.

3.4. *Persea Americana*

Persea americana belongs to the family *Lauraceae*a along with cinnamon, camphor, and bay laurel. . Avocados are commercially valuable and are cultivated in tropical and Mediterranean climate throughout the world. They are a green skinned, fleshy body that may be pear shaped egg shaped or spherical and ripens after harvesting. It is commonly called in English as avocado, in Yoruba “igba”, ibo “Ube-beke” and Swahili “mparachichi, mpea, mwembe mafuta”.

Avocado has been shown to possess valuable phytochemicals. These compound classes may be divided into alkanols (also sometimes termed "aliphatic acetogenins"), terpenoid glycosides, various furan ring-containing derivatives, flavonoids, and a coumarin. The

highly functionalized alkanols [218,219-221] of avocado have exhibited quite diverse biological properties thus far. For example, Oberlies *et al* isolated 1, 2, 4-trihydroxyheptadec-16-ene, 1, 2, 4-trihydroxyheptadec-16-yne , and 1, 2, 4 -trihydroxynonadecane from the unripe fruits of *P. americana*, and found these substances to be moderately cytotoxic when evaluated against a small panel of cancer cell lines [219].Kawagishi *et al* isolated 5 alkanols from avocado fruits with "liver suppressing activity" (as determined by the changes in plasma levels of alanine aminotransferase and aspartate aminotransferase), including compounds 9-11[221]

Avocado has sometimes received the reputation as a fruit too high in fat. While it is true that avocado is a high-fat food (about 85% of its calories come from fat), the fat contained in avocado is unusual and provides research-based health benefits. The unusual nature of avocado fat is threefold. First are the phytosterols that account for a major portion of avocado fats. These phytosterols include beta-sitosterol, campesterol, and stigmasterol and they are key supporters of our inflammatory system that help keep inflammation under control [222]. The anti-inflammatory benefits of these avocado fats are particularly well-documented with problems involving arthritis. Second are avocado's polyhydroxylated fatty alcohols (PFAs). PFAs are widely present in ocean plants but fairly unique among land plants—making the avocado tree (and its fruit) unusual in this regard. Like the avocado's phytosterols, its PFAs also provide us with anti-inflammatory benefits [223]. Third is the unusually high amount of a fatty acid called oleic acid in avocado. Over half of the total fat in avocado is provided in the form of oleic acid—a situation very similar to the fat composition of olives and olive oil. Oleic acid helps our digestive tract form transport molecules for fat that can increase our absorption of fat-soluble nutrients like carotenoids [224]. As a monounsaturated fatty acid, it has also been shown to help lower our risk of heart disease [225]. Hence its reputation as a fruit high in fat is of great importance in maintain the the integrity of the heard. Like other high-fat plant foods (for example, walnuts and flaxseeds), avocado provides unique health benefits precisely because of its unusual fat composition.

Avocados are also good source of Vitamin K, dietary fiber, Vitamin B6, Vitamin C, Folate and copper. Avocados are also a good source of potassium: they are higher in potassium than a medium banana. They also contains essential nutrients such as carbohydrates, sugar, soluble and insoluble fiber, It is also good source of oil containing monounsaturated fat its oil contents varies depending on its varieties and the period of extraction of oil by cold-press process. Avocado is a rich source of mineral [226]. The presence of the above mentioned phtytochemicals and vitamins makes avocado fruit a rich source of antioxidants hence capable of preventing quite a large number of diseases which are usually as a result of excessive free radical generation. For instance avocado has the ability to help prevent the occurrence of cancers in the mouth, skin, and prostate gland. This has been studied at a preliminary level by health researchers, mostly through the use of cancer cells or lab studies involving animals and their consumption of avocado extracts. But even though this anti-cancer research has been limited with respect to humans and diet, it is believed that the preliminary results are impressive. The anti-cancer properties of avocado are definitely

related to its unusual mix of anti-inflammatory and antioxidant nutrients [227]. That relationship is to be expected since cancer risk factors almost always include excessive inflammation (related to lack of anti-inflammatory nutrients) and oxidative stress (related to lack of antioxidants). But here is where the avocado story gets especially interesting. In healthy cells, avocado works to improve inflammatory and oxidative stress levels. But in cancer cells, avocado works to increase oxidative stress and shift the cancer cells over into a programmed cell death cycle (apoptosis), lessening the cancer cell numbers [228]. In other words, avocado appears to selectively push cancer cells "over the brink" in terms of oxidative stress and increase their likelihood of dying, while at the same time actively supporting the health of non-cancerous cells by increasing their supply antioxidant and anti-inflammatory nutrients.

4. Antioxidant properties of mushrooms

Mushrooms have been used for many years as nutritional food and food flavouring materials as well as medicines [229]. Because of their flavour and aroma, mushrooms are greatly appreciated in many countries. According to the definition of Chang and Miles [230], a mushroom is 'a macrofungus with a distinctive fruiting body, which can be hypogeous or epigeous, large enough to be seen with the naked eye and to be picked by hand'. They constitute at least 14 000 and perhaps as many as 22 000 known species. The number of mushroom species on the earth is estimated to be 140 000, suggesting that only 10% are known [231]. Research indicates mushrooms have potential antiviral, antimicrobial, anticancer, antihyperglycemic, cardioprotective, and anti-inflammatory, activities.

A number of bioactive molecules, including antitumor substances, have been identified in many mushroom species. Polysaccharides are the best known and most potent mushroom derived substances with antitumor and immunomodulating properties [232,233]. Historically, hot-water-soluble fractions (decoctions and essences) from medicinal mushrooms, i.e., mostly polysaccharides, were used as medicine in the Far East, where knowledge and practice of mushroom use primarily originated [234). Mushrooms such as *Ganoderma lucidum* (Reishi), *Lentinus edodes* (Shiitake*), Inonotus obliquus* (Chaga) and many others have been collected and used for hundreds of years in Korea, China, Japan, and eastern Russia. Those practices still form the basis of modern scientific studies of fungal medical activities, especially in the field of stomach, prostate, and lung cancers. It is notable and remarkable how reliable the facts collected by traditional eastern medicine are in the study of medicinal mushrooms [235].

They are reputed to possess anti-allergic and anticholesterol activities. Aqueous extracts from *Pleurotus sajor caju* have been proven good in renal failure [236] showed mushrooms cure epilepsy, wounds, skin diseases, heart ailments, rheumatoid arthritis, cholera besides intermittent fevers, diaphoretic, diarrhea, dysentery, cold, anesthesia, liver disease, gall bladder diseases and used as vermicides.

Ganoderma lucidum are known to lower blood pressure and serum cholesterol concentration of hypertensive rats [237]. *Lentinus tigrinus* and *G. lucidium* are proved anticholesterolmic

[238]. *Lentinus edodus* has been used to enhance vigour, sexuality, energy and as an anti aging agent [239]. Lentinan sulphate obtained from *Lentinus* species inhibits HIV [239]. Jong et al. [240] reported that mushrooms cause regression of the disease state. Puffballs have been used in urinary infections [241]. Maitake extract has been shown to kill HIV and enhance the activity of T-helper cells [242,243] *Ganoderma* nutriceuticals have also exhibited promising antiviral effects like, anti-hepatitis B [243]Kino et al., 1989), anti-HIV [245,246]Kim et al., 1993; Liu and Chang, 1995). Dreyfuss and Chapela ([247] reported hundreds of secondary metabolites of fungal origin possessing biological activity. Mushrooms act as biological response modifiers by promoting the positive factors and eliminating the negative factors from the human body and thus regarded as the fourth principal form of the conventional cancer treatment.

Karst is believed to act as an anti-inflammatory and antidiabetic agent [248]. It is also used by Indian tribals for treating joint pain [249] Various reported medicinal uses of mushrooms like *reishi, cordyceps, enoki, maitake*, *lion's mane* and *splitgill* have been reported for cancer treatment; *shiitake, blazei, reishi, enoki, cordyceps, maitake, mesima* and oyster were found effective against cholesterol reduction. Reishi, cordyceps, shiitake and maitake is used for reducing stress. Lion's mane has been used for memory improvement; reishi for inducing sleep cordyceps for physical endurance and sexual performance, reishi, cordyceps, chaga and lion's mane for asthma and allergy treatment. They are also believed to be a good health elevator [250]. Auricularia species were used since times for treating hemorrhoids and various stomach ailments [251]. Pleurotus tuber-regium mushroom have been used for curing headache, high blood pressure, smallpox, asthma, colds and stomach ailments [252,253]. It has been reported *that P. ostreatus* lowers the serum cholesterol concentration in rats [254]. Puffballs (*Clavatia, Lycoperdon*) have been used for healing wounds [255]. Fresh mushrooms are known to contain both soluble and insoluble fibres; the soluble fibre is mainly beta-glucans polysaccharides and chitosans which are components of the cell walls [256]. Soluble fibre present in mushrooms prevents and manages cardiovascular diseases [257]. Wasser [258] reported that mushroom health supplements are marketed in the form of powders, capsules or tablets made of dried fruiting bodies, extracts of mycelium with substrate, biomass or extract from liquid fermentation. *P. sajor-caju* has been found to be inductive for growth of probiotic bacteria [259]. *Cordyceps sinensis* also treated as half caterpillar and half mushroom has been known and used for many centuries in traditional Chinese medicine. *Cordyceps* has been used to induce restful sleep, acts as anticancer, antiaging, and antiasthama agents besides proved effective for memory improvement and as sexual rejuvenator [260].

The antioxidant properties of mushroom have been reported. They are regarded as organisms which possess naturally occurring antioxidants. This is correlated with their phenolic and polysaccharide compounds [261]). Mau et al. [262] found antioxidant properties of several ear mushrooms. Tyrosinase from *A. bisporus* is antioxidant [180]. Lakshmi et al. [263] determined antioxidant activity of *P. sajor caju*. [264] observed that triterpenoides are the main chemical compounds in *G. lucidium.*

Three species of *Pleurotus florida, P. pulmonarius and P. citrinopileatus* were examined for their antioxidant potentialities with a view to popularize medicinal mushrooms among common middle class people at low-cost instead of administering costly medicines. Reducing power, chelating activity of Fe^{2+} and total phenol were observed to be higher in *P. florida* than in *P. pulmonarius* and *P. citrinopileatus* respectively. Among antioxidative enzymes, *P. florida* exhibited highest peroxidase and superoxide dismutase (SOD) where as catalase activity was found to be highest in *P. pulmonarius* [265]. The alcohol and aqueous extracts of *G. lucidum* and *C. sinensis* showed a high anti-oxidative activity by giving protection against oxidative DNA damage[266]. The reducing power and chelating activity of Fe^{2+} of *G. lucidum* and *C. sinensis* ethanol extract has been shown to increase with increase in concentration. The *G. lucidum* ethanol extract showed higher anti-oxidative properties than *C. sinensis*, probably due to differences in the compounds present in the fruiting bodies [267]. Previous workers obtained 6.001+0.04 μmg-1, 7.501+0.10 μmg^{-1} and 6.72+0.05 μmg^{-1} of phenol components in ethanol extract of *P. sajor-caju, P. florida* and *P. aureovillosus* respectively [268, 269]. It is showed that antioxidant activity of *Phellinus rimosus* seems to be more effective than the *Pleurotus florida, P. sajour-caju* and *G. lucidum* [263,270]. Fruiting bodies of medicinal mushroom (*G. lucidum*) contain polysaccharides, triterpenoids, adenosine, germanium, protein (L2-8), amino acids which have been found to have antitumor and immuno-modulating affect [271]. Methanol extract of *P. rimosus* have been shown to effectively reduce ferric ion in FRAP assay and scavenged DPPH radicals [272].

Extracts from fruiting bodies and mycelia of *G. lucidum* occurring in South India were found to possess *in vitro* antioxidant activity [266] and antimutagenic activities [263]. Antioxidant assays of the ethyl acetate, methanol and aqueous extract of *G. lucidum* effectively scavenged the O_2 and OH radicals [272]. However the aqueous extract was not effective to inhibit the ferrous ion induced lipid peroxidation [266] The extract showed significant reducing power and radical scavenging property as evident from FRAP assay [272] and DPPH radical scavenging assay [263,272]. The antioxidant potential of *L. edodes* methanol extract was investigated in the search for new bioactive compounds from natural resources. The measured DPPH radical scavenging activity is depicted by Sasidharan et al. [273]. The free radical scavenging activities were 39.0%, 41.0% and 66.00% for the *L. edodes* extract, vitamin E and BHT, respectively. The EC50 value is 4.4 mg/mL (y = 11.7x - 1.693, R2 = 0.988) which is the concentration of the crude extract that decreases the initial DPPH radical concentration by 50%. Effectiveness of antioxidant properties was found to be inversely correlated with EC50 values. Cheung and Cheung [274] also reported the antioxidant activity of *L. edodes* against lipid peroxidation. They found that the low molecular weight sub-fraction of the water extract of *L. edodes* had the highest antioxidant activity against lipid peroxidation of rat brain homogenate, with IC50 values of 1.05 mg/mL. In addition, other mushrooms have also been reported to possess antioxidant activity. Wong and Chye [275] reported the antioxidant activity of *Pleurotus porrigens, Hygrocybe conica, Xerula furfuracea (Rooted oude), Schizophyllum commune, Polyporus tenuiculus (Pore fungus)* and *Pleurotus florida*. Petroleum ether (PE) and methanolic extracts from these edible wild mushrooms were effective in DPPH radical scavenging and metal chelating ability. PE extracts were more effective than

methanolic extracts in antioxidant activity using the DPPH, whereas methanolic extracts were more effective in reducing power and metal chelating ability.

5. Chemoprotective effects of African vegetables, fruits and mushrooms against mycotoxin induced oxidative stress and diseases

There are compelling evidences to show that mycotoxins are amongst the dietary factors that contribute to the risk of several types of diseases. The toxicologist and Nutritionist are particularly interested in mycoxins such as aflatoxins, ochratoxin A, fumonisins, Zeralenone and deoxynivalenol as they are attributed to the implication of several disease conditions.

Aflatoxin BI is the commonest form of Aflatoxin which is produced by *Apergillus flavus*. It is has been implicated in quite a number of diseases including, kwarshiorkhor, hepatitis, lung cancer, and liver cancer. It can either cause cancer alone or in synergy with hepatitis [276]. Cancer is induced by Aflaxoxin BI via metabolic activation by CYP3A4, CYP3A5 and/ or CYP1A2 [277, 278] to exo-8,9-epoxide which can form adduct with DNA leading to guanine nucleotide substitutions [279] specifically to codon 249 of the p53 gene [280]. Epidemiological studies have shown increased codon- 249 p53 mutations in areas of high aflatoxin B1 exposure [281]. Since hepatitis B virus and aflatoxin exposure have also been linked to hepatocellular carcinoma, recent studies have shown the interactive effect of increasing p53 mutation in persons with hepatitis B and coexposure to aflatoxin [282].

Ochratoxin A, a toxin produced by *Aspergillus ochraceus, Aspergillus carbonarius* and *Penicillium verrucosum,* is one of the most abundant food-contaminating mycotoxins [283]. It is found as contaminant in human foods, including various cereals, coffee, cocoa, wines and dried fruits. Depending on the dose, OTA may be carcinogenic, genotoxic, immunotoxic or teratogenic and even neurotoxic [284]. Exposure to OTA has been associated with the incidence of a kidney disease in humans, involving chronic interstitial nephritis as well as tumours of the urinary tract termed Baslkan Endemic Nephropathy (BEN) because of its geographical distribution [285]. It has been reported that occurrence of OTA with aflatoxin B1 in the same crop potentiates the mutagenic ability of the latter [286].

Zearalenone (ZEA) is a mycotoxin produced mainly by fungi belonging to the genus Fusarium in foods and feeds. It is frequently implicated in reproductive disorders of farm animals and occasionally in hyperoestrogenic syndromes in humans. It is found worldwide in a number of cereal crops such as maize, barley, wheat, oats and sorghum [287]. A wide variety of clinical effects attributed to zearalenone have been described in the literature. Decreased fertility, abnormal estrus cycles, swollen vulvas, vaginitis, reduced milk production and mammary gland enlargement are the most common findings reported in cattle and swine. ZEA binds to estrogen receptors influencing estrogen dependent transcription in the nucleus [288]. Receptor binded by ZEA has been shown to inhibit the binding estrogenic hormones in rat mammary tissues [289]. It was reported also by Hagler [290] that zearalenone causes hyperoestrogenism in swine. The

potential for Zearelenon to stimulate growth of human breast cancer cells has also been demonstrated [291].

Fumonisins are a family of toxic and carcinogenic mycotoxins produced by *Fusarium verticillioides* (formerly *Fusarium moniliforme*), a common fungal contaminant of maize [292] Studies have shown the implication of fumonisins in the aetiology of a number of diseases such as rat liver cancer and haemorrhage in the brain of rabbits [293]. It has been reported that Fumonisin induce apoptosis in cultured human cells [294] and nephrotoxicity in certain animals [295].

Although fumonisin contaminated food has not been conclusively linked to human health harzards however a few studies have associated consumption of maize contaminated with fuminisins to human oesophageal carcinoma in some parts of South Africa and China [296]. Recently fumonisin toxicity has been linked reactive oxygen species (ROS) damage. For Instance It was reported that there was increase in lipid peroxidation, production of ROS, increase in caspase-3- like protease activity, internucleosomal DNA fragmentation and intracellular reduction of glutathione in human U-118MG glioblastoma cells treated with fumonisin B1 [297].

Deoxynivalenol (also called DON or vomitoxin) is one of an array of trichothecene mycotoxins produced by *Fusarium graminearum* and several other species of Fusarium that cause Fusarium head blight (also called FHB or scab) of wheat, barley, and other grasses and ear and stalk rot of corn. DON does not constitute a significant threat to public health. In a few cases short-term nausea and vomiting have been recorded [298].

The protective effect of various extract of *Vernonia amygdalina* on breast and prostate cancer has earlier been reported above. Mycotoxins such as Aflatoxin B1 are potent causative agent of several forms of cancer and this result from oxidative damage on macromolecules like DNA, proteins, lipids and carbohydrates. Vegetables, fruits and mushrooms have been reported to be reservoirs of antioxidants capable of scavenging and chelating reactive oxygen species thus preventing and protecting against such diseases arising from mycotoxin induced oxidative damage. For instance It was shown in a study that a diet incorporated with VA protected weanling albino rats against aflatoxin B1-induced hepatotoxicity [299]

Recent findings on the cause of cancer reveal that the damage caused by free radical to DNA is one of the reasons for carcinogenesis. The *Ocimum sanctum* has been well known for its antioxidant property with active ingredient such as eugenol and hence the plant has been studied for its anticancer activity. The protective effect of alcoholic extract of the leaves of

Ocimum sanctum on 3-methylcholanthrene (MCA), 7,12-dimethyl-benzanthracene (DMBA) and aflatoxin B, (AFB(1)) induced skin tumorigenesis in a mouse model was reported[300]. The extract of *Ocimum sanctum* leaf was shown to provide protection against chemical carcinogenesis in one or more of the following mechanisms: (i) by acting as an antioxidant; (ii) by modulating phase I and II enzymes; (iii) by exhibiting antiproliferative activity [300].

Treatment with aqueous and ethanolic extracts of *Ocimum sanctum* at 50μg/ml in mice bearing Sarcoma-180 solid tumors mediated a significant reduction in tumor volume and an increase in lifespan.These findings conclude *Ocimum sanctum* extracts possess anticancer activity [301].

Several studies have been reported to show that different types of fruits and vegetables are valuable sources of nutraceuticals. According to several studies as noted above these fruits and vegetables have high values of important nutrients and phytochemicals which exhibit antioxidant functions hence many form of diseases arising from the consumption of mycotoxin contaminated food can be protected. Lycopene, a carotenoid is present in many fruits and vegetables; such as grapefruit, guava, watermelon ansd pawpaw however, tomatoes and processed tomato products constitute the major source of lycopene [302]. Several studies have indicated that lycopene is an effective antioxidant and free radical scavenger. Lycopene, because of its high number of conjugated double bonds, exhibits higher singlet oxygen quenching ability compared to β-carotene or α-tocopherol [303]. In *in vitro* systems, lycopene was found to inactivate hydrogen peroxide and nitrogen dioxide [304, 305]. Using pulse radiolysis techniques, Mortesen *et al.* [306] demonstrated its ability to scavenge nitrogen dioxide ($NO_2^{\cdot}$), thiyl ($RS^{\cdot}$) and sulphonyl ($RSO_2^{\cdot}$) radicals. Lycopene is highly lipophilic and is most commonly located within cell membranes and other lipid components. It is therefore expected that in the lipophylic environment lycopene will have maximum ROS scavenging effects. Hsiao et al. [307] showed the scavenging activity of lycopene on DPPH radical in rat brain homogenates and its ability to inhibit nitric oxide formation in cultured microglia stimulated by lipopolysaccharide. They further reported the protective effect of lycopene on ischemic brain injury *in vivo.*Epidemiological data strongly imply that lycopene consumption and tomato products contribute to prostate cancer risk reduction via different mechanisms which cooperate in reducing the proliferation of normal and cancerous prostate epithelial cells thereby reducing DNA damage and improving oxidative stress defense from free radicals arising from mycotoxins. . The mechanisms include inhibition of prostatic IGF-I signaling, IL-6 expression, and androgen signaling ([308] Moreover, lycopene improves gap-junctional communication and induces phase II drug metabolizing enzymes as well asoxidative defense genes. Lycopene was also demonstrated to inhibit mitogen-activated protein kinases, such as ERK1/2, p38 and JNK, and the transcription factor, nuclear factor-kappaB [309]

Mushrooms have been reported as useful in preventing diseases such are hypertension, hypercholesterolemia, cancer and other diseases linked to reactive oxygen species damage their extracts may act as biological response modifiers with anticancer activities. Though the mechanism of their antitumor actions is still not completely understood, stimulation and modulation of key host immune responses by these mushroom polymers appears central.

A study on the protective effect of some edible mushrooms on aflatoxin B1 induction revealed that mushroom at low doses of 100mg/Kg and 200mg/Kg body weight significantly reduced aflatoxin B1 toxicity [310]. The Liver function enzymes, AST. ALT and marker of kidney function, uric acid and creatine was shown to be reduced significantly on treatment

with the extract of mushroom species while the antioxidant superoxide dismustase was significantly increased when compared to the aflatoxin B1 induced rats.

6. Conclusion

This chapter has reviewed only few vegetables, fruits and mushrooms with chemopreventive and antioxidant properties in African which validates some of the acclaimed traditional use. There is still a great deal of vegetables, fruits and mushrooms in African whose antioxidant studies has been carried out both at the preliminary and advanced stage. The consumption of these vegetables, fruits and mushrooms is capable of preventing and protecting against some of the diseases arising from the ingestion of mycotoxin contaminated foods in both humans and livestock.

Author details

R.U. Hamzah, A.A. Jigam, H.A. Makun, and E.C. Egwim
Department of Biochemistry, Federal University of Technology, Minna, Niger State, Nigeria

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