Chemistry Research Journal, 2020, 5(4):161-175

Available online www.chemrj.org

Research Article

ISSN: 2455-8990
CODEN(USA): CRJHA5

A Brief Review on the Composition, Proximate and Elemental Analysis of the Nigerian Walnut (*Tetracarpidium conophorum*)

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Abstract Walnut *(Tetracarpidium conophorum)* is majorly cultivated principally for its nuts in Southern Nigeria, they are cooked and eaten as snacks. They are a great source of unsaturated fatty acids, vitamin E, fiber, magnesium and potassium and are known to be considerably rich in omega-6 and omega-3 polyunsaturated fatty acids which are highly beneficial to to human health. The current review appraises the elemental (Sodium, potassium, calcium, magnesium, Iron, copper, zinc lead) and proximate (ash content, moisture content, fat content, protein content, total carbohydrate) analyses of the Nigerian walnut, as well as other composition contents such as ascorbic acid content, alkaloid, tocopherols, sterols and dietary fibres. The therapeutic properties ranging from its ability to be used traditionally as a curative agent for fever, asthma, rheumatismal pains, diabetes etc. have also been properly discussed.

Keywords walnut; protein content; fat content; alkaloids; therapeutic

1. Introduction

Nuts have been part of the human diet for a long time; remains have been found in archaeological sites dating back to before 10,000 BC [1]. Nuts are concentrated food and generally store well. Recent research suggests that some early civilizations relied on nuts as as taple food before cereal grains [1-2]. The world production of nuts is low compared to other food types but the prospect for increasing production is good [1]. Nuts are highly valued for their attractive delicate taste, also known as organoleptic characteristics [3]. Their most positive feature is the increasing number of reports indicating that the regular consumption of nuts may have a positive effect on a person's health; nuts are nutrient dense foods rich in unsaturated fatty acids and other nutritional compounds such as protein, carbohydrate, fiber and minerals [4]. For a long time vegetarians have valued nuts as an alternative source of protein, but nuts have more than protein to offer. Nuts are highly beneficial to human health because of their unique composition [5-6].

Nuts are a main source of unsaturated fatty acids, vitamin E, fiber, magnesium and potassium [7]. Among the nuts, which contain mostly monounsaturated fatty acids, walnuts are considerably rich in omega-6 and omega-3 polyunsaturated fatty acids [8]. These compounds are also favorable to human health, since they are able to act as protection by different ways such as: regular consumption of them may supply some protection against coronary heart disease [9-10], magnesium and potassium may regulate blood pressure [11] and they are believed to possess plasma cholesterol-lowering properties [12].

Walnuts, common name for small flowering plants are very important because of the nuts and timber most of them produce for its representative genus [13]. Walnut comprises such families as *Juglandaceae* (English walnut), *Euphorbiaceae* and *Olacaceae* (African walnut) [14]. Each family has its own peculiar characteristics but they have some things in common such as the nuts. *Juglandaceae* is mostly found in the Southeast Europe, to Japan and more widely in the new world.

Walnut tree (*Juglans regia* L.), is native to Eastern Europe and North Asia, but is also found throughout North, Central and South America [15]. It is a member of Juglandaceae family, one of the finest nuts of temperate regions [16] and the oldest cultivated fruit in the world and grown spontaneously almost all over Turkey [17]. The tree has great socio-economic importance being frequently cultivated in temperate zones of the world mainly because of its edible seed, whose oil is rich in unsaturated fatty acids, phytosterols and tocopherols [8,18] and whose consumption has recently been related to health benefits [12,19]. Moreover, its non-edible parts such as leaves, husks and wood also find broad application; its use is reported to flavour liqueurs [20-22], in cosmetics [23], in dyes [24], furniture and in traditional medicine [25]. In Pakistan there are up to 50 different walnut cultivars growing in different regions of Pakistan like Chitral, Dir, Swat, Gilgit, Kaghan, Baltistan, Kurrum and Muzafarabad [26]; Iran has about 250000 hectares of land under walnut cultivation [27]. Walnut is cultivated in some regions such as Kerman, Hamedan, Qazvin, East-Azarbayjan, Kermanshah, Khorasan and Fars [28]. After china and USA, Iran is third biggest producer of walnut in the word and just in 2010; Iran produced 270300 tons of walnut with shell [27].

The most important walnut varieties in Turkey are Sebin, Yalova 1, Yalova 2, Yalova 3, Yalova 4 and Bilecik [29], while walnut cultivars (*Mihaela, Roxana, Velnita, Geoagiu 65, Jupanesti, Valcor, Valmit, Valrex, Argesan*) originated from Romania [30]. Walnuts (*Juglans regia* L.) are widely distributed all over the world, and they are common in China. On a global basis, walnuts rank second behind almonds in tree nut production and in 2010, global production of walnuts was 1,500,000 t [31]. China leads the world production of walnuts, followed by the US, thus, China accounted for 33.33% of global walnut production in 2010 [31].

Tetracarpidium conophorum (family *Euphorbiaceae*) is found in Nigeria and Cameroon while *Coula edulis* (family Olacaceae) which is also referred to as African walnut is found in Congo, Gabon and Liberia [32]. *Tetracarpidium conophorum* is known as *Ekporo* by the Efiks and Ibibios of Cross River and Akwa ibom states of Nigeria [33]. In the littoral and the western Cameroon, walnut is known as *kaso or ngak* [34], while in the Western Nigeria, it is known as *awusa or asala* (Yoruba). *Tetracarpidium conophorum* is known in the Southern Nigeria as ukpa (Igbo). In this region, this plant is cultivated principally for the nuts which are cooked and consumed as snacks [35].

In recent times, researchers have been exploring the composition of walnut woods, roots, barks, seed shells and kernels for nutritional and therapeutic functions [15,33]. Ripe walnuts are mostly eaten as dessert nuts or used in cakes, desserts and confectionery of all kinds from ice cream to Baklava [16]. The presence of tannins in the seed of *Tetracarpidium conophorum* can support its strong use for healing of haemorrhoids, frost bite and varicose ulcers in herbal medicine [36-37]. The result of mineral composition clearly shows that *Tetracarpidium conophorum* seed contains rich source of mineral elements [14]. Furthermore, a number of adsorption studies have been carried out on walnut seed shells. Activated carbon produced from the walnut seed shell has been reportedly used to adsorb trace metals like Cr, Pb, Cd, etc [38-40].

Authors have used different equipment in the analysis of walnut seed for the determination of various elements including Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) [30], Inductively Coupled Plasma–Atomic Emission Spectroscopy (ICP-AES) [16,41,42], Atomic Absorption Spectrophotometry [13,14,26,27,43], etc. Therefore, a highlight of this brief review is on the elemental, proximate and composition of the Nigerian walnut *(Tetracarpidium conophorum)*, as well as its health benefits and therapeutic effects.

2. Walnut and its physical composition

Tetracarpidium conophorum trees (Nigerian walnut) are found in Uyo, Akamkpa, Akpabuyo, Lagos, Kogi, Ajaawa-Ogbomoso and Ibadan [13]. They are also found in Imo and Abia states, but not as ubiquitous as in afore mentioned cities. This plant is cultivated principally for the nuts which are cooked and consumed as snacks [35]. Walnut seed

possesses a bitter taste, which is usually observed upon drinking water immediately after eating. This could be attributed to the presence of chemical substances such as alkaloid, as other researchers have identified [13]. Walnuts are of a high economic interest for the food industry [44] and its nuts are highly appreciated for its unique organoleptic characteristics [3], hypocholesterolemic effects [45-49] and antihypertensive effect [45,50,51].

Walnut, including the tree, nut, shell and kernel (commonly consumed part) are of invaluable economic importance to human. *Tetracarpidium conophorum* is a climbing shrub 10-20 ft long [13-14] and climbs any available tree it is planted close to. Figure 1, describes walnut plant climbing a cocoa tree close to where it was planted.

Figure 1: Walnut tree as a climber (climbing cocoa tree) [13]

The nut consists of the shell and the kernel, otherwise known as the seed. Figures 2 and 3 respectively show nut of walnut samples with shelled and kernel i.e nut whose shell has been removed. It can be seen from the picture below that the shell is brown in colour while the kernel is white in colour but is covered with light brown coloured mesh-like coat. Sen and Tekintas [52] conducted study on the selection of Adilcevaz walnut. The study comprised the physical composition of walnut in which they reported a nut weight of 5.45 – 11.42 g and kernel weight of 2.13 – 6.57 g, giving kernel ratio 39.01 – 57.53 %. Similar results were obtained by Ozcan and Koyuncu [29] in their study of the physical and chemical composition of some walnut (*Juglans regia* L.) genotypes grown in Turkey. They found the mean nut weight of walnut sample ranging from 8.43 ± 0.82 to 11.09 ± 0.84 g. Mean kernel weight was between 4.35 ± 0.05 and 5.00 ± 0.45 g, while the percentage kernel ranged from 48.89 ± 3.24 to 57.41 ± 2.50 %. They further reported mean shell thickness ranging 0.83 ± 0.08 to 1.47 ± 0.20 mm; nut thickness of 29.53 ± 0.92 – 33.45 ± 3.47 mm; nut length between 29.72 ± 1.82 and 37.88 ± 0.83 mm and nut diameter ranging from 27.68 ± 0.75 to 31.12 ± 1.29 mm. They stated that the shape of nut was either spherical or oval. Literature also reported the study of physico-chemical properties, fatty acid and mineral content of some walnuts (*Juglans regia* L.) types by Özcan *et al*. [42]. The report of the mean weight of nut with shell was in the range of 12.96 ± 1.00 – 15.74 ± 0.02 g; diameter of nut with shell was between 36.72 ± 1.22 and 41.02 ± 0.98 mm; shell weight ranging from 4.3256 ± 0.0100 to 7.7585 ± 0.0005 g and kernel weight between 6.5872 ± 0.0198 and 8.9289 ± 0.0200 g.

Figure 2: Nuts of walnut with shell [13]

Figure 3: Kernels of walnut released from shell [13]

2.1. Proximate composition of walnut

Proximate composition of walnut include its: ash content, moisture content, fat, protein and total carbohydrate.

2.1.1. Ash content

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food. Ash contents of fresh foods rarely exceed 5%, although some processed foods can have ash contents as high as 12%, *e.g.*, dried beef. The higher the percentage ash content of any sample, the higher the mineral content. Ashing may also be used as the first step in preparing samples for analysis of specific minerals by atomic spectroscopy.

Several authors have reported ash content of walnut of different cultivars, genotypes as well as species. Koyuncu and Askin [53] conducted a study on determination of main composition of promising walnut genotypes selected from Adilcevaz (Bitlis) and reported ash content of 1.68 – 2.06%. This was in line with the range obtained by Ozkan and Koyuncu [29], which was 1.26 – 2.06%. Reports from Dogan and Akgulb [48], Ozcan *et al*. [42] and Ali *et al*.

[26] showed ash content of various walnut cultivars to be in ranges of 1.93 – 2.19%, 1.985 – 2.525% and 1.27 – 1.95% respectively. Al-Bachir [54], Ozcan [16], Savage [2] and Edem *et al.* [33] obtained ash content of 1.26%, 1.57%, 1.80% and 2.03% respectively from various walnut samples they studied. However, Ayoola *et al.* [14] and Pereira *et al.* [49] obtained rather higher values of ash content in their study. The latter studied six walnut cultivars in Purtagal and found the ash contents to be between 3.31 – 4.26%, while the former's 5.27 percentage ash content was slightly above the results obtained by different authors above.

2.1.2. Moisture content

Moisture content is one of the most commonly measured properties of food materials. It is important to consider the moisture content of food, which gives the suitability of the food for consumption, because moisture content affects the physical and chemical aspects of food which relates with the freshness and stability for the storage of the food for a long period of time.

This parameter is important to food scientists for a number of different reasons:

1. *Legal and Labeling Requirements:* There are legal limits to the maximum or minimum amount of water that must be present in certain types of food.
2. *Economic:* The cost of many foods depends on the amount of water they contain - water is an inexpensive ingredient, and manufacturers often try to incorporate as much as possible in a food, without exceeding some maximum legal requirement.
3. *Microbial Stability:* The propensity of microorganisms to grow in foods depends on their water content. For this reason many foods are dried below some critical moisture content.
4. *Food Quality:* The texture, taste, appearance and stability of foods depend on the amount of water they contain.
5. *Food Processing Operations:* Knowledge of the moisture content is often necessary to predict the behavior of foods during processing, *e.g.* mixing, drying, flow through a pipe or packaging.

In addition to the above reasons, it became obvious to researchers that water content of food samples acts as diluents, hence, contents of the food samples are reported either on wet or dry basis. Several authors have reported moisture content of walnut in several cultivars and genotypes, depending on countries or regions. Literatures show moisture contents of various cultivars of walnut from regions and countries other than Nigeria to be below 5%. Ozkan and Koyuncu [29] presented the mean moisture content (3.25 ± 0.08 – 3.91 ± 0.26%) of some genotypes of walnut from a data collected for two years. Their result was similar to those obtained by Dogan and Akgulb [48], Al-Bachir [54] and Pereira *et al*. [49], which were 3.00 ± 0.09 – 3.5 ± 0.02%, 3.48% and 3.85 – 4.50% respectively. Moisture contents valued at 2.98 %, 2.71 ± 0.71% and 2.76 – 4.20% were obtained by Çağlarırmak [55], Ozcan [16] and Ali *et al*. [26] respectively. Ayoola *et al.* [14] and Edem *et al.* [33] studied *Tetracarpidium conophorum* seeds (African walnut) and obtained very high moisture contents of 41.5% and 48.70% respectively. This indeed was very high compared to the previously presented results and suggests that disparity exists between the walnut species grown in Nigeria and other countries.

2.1.3. Fat content

Turkish walnut (*Juglans regia*) cultivars and genotypes grown in subtropical climate of eastern Mediterranean region had been found to contain total fat ranging between 51.73 ± 3.44 and 56.31 ± 1.00% [4]. This was in agreement with other literatures detailing the determination of fat in walnuts that are not from Nigeria. For example, Al-Bachir [54], Pereira *et al.* [49], and Ali *et al.* [26] obtained 67.35%, 68.83 – 72.14% and 63.54 – 69.92% respectively as fat contents of various genotypes of walnut; while 61.97 ± 0.44 – 70.92 ± 0.61% was the range of mean fat content of walnut samples analysed by Ozkan and co-workers [29]. In contrast to the high fat content of walnut in these regions, *Tetracarpidium conophorum* seeds (Nigerian walnut) possess a low fat content in comparison; Ayoola *et al.* [14] obtained 7.34% while Edem *et al.* [33] obtained 6.21%. Although walnuts are rich in fat, a diet supplemented with walnuts had a beneficial effect on blood lipids, lowering blood cholesterol and lowering the ratio of serum concentrations of low density lipoprotein: high density lipoprotein by 12% [12].

2.1.4. Protein content

Protein is any of a large number of organic compounds that make up living organisms and are essential to their functioning. Protein molecules range from the long, insoluble fibers that make up connective tissue and hair to the compact, soluble globules that can pass through cell membranes and set off metabolic reactions [56]. They are all large molecules, ranging in molecular weight from a few thousand to more than a million, and they are specific for each species and for each organ of each species. Plant proteins play significant roles in human nutrition, particularly in developing countries where average protein intake is less than that required. Plant protein products are gaining increased interest as ingredients in food systems throughout many parts of the world and the final success of utilizing plant proteins as additives depends greatly upon the flavor characteristics that they impart to foods [33]. Studies have shown that African walnut can contain as high as 30% of protein. Earlier study by Edem and co-workers depicted crude protein content as high as 35.22% in *Tetracarpidium conophorum* seeds [33]. However, Ayoola *et al.* [14] studied Nigerian walnut and obtained protein content of 21.65%. This value is close to the result (18 ~ 24%) obtained by Mao and Hua [31] while they studied another species, *Juglans regia* L. Other values that had been described by literatures were 14.6%, 13.77%, 14.38 – 18.08% and 22.85% respectively [16,49,54,55]. Reports by Ozcan *et al*. [42], Ozkan and Koyuncu [29] and Dogan and Akgulb [48] presented the protein contents of walnut in ranges of 7.242± 1.878 –8.101 ± 0.055%, 15.17 ± 0.13 – 19.24 ± 0.15% and16.23 ± 0.09 – 17.47 ± 0.02% respectively.

Furthermore, walnuts are an excellent source of protein (protein is made up of individual amino acids some of which are essential in the diet), the protein content of New Zealand walnuts range from 13.6 to 18.1 g crude protein/100 g DM . In the same study [57] the amino acid composition of New Zealand grown walnuts were consistent between the 12 different cultivars except for the two American cultivars, Tehama and Vina which showed lower amino acid contents. These lower values reflect the lower crude protein contents of these two cultivars. Walnuts contain a relatively low content of lysine and high levels of arginine [58]. Savage [2] showed that the ratio for 12 different cultivars grown in New Zealand to be 0.24 which is much lower than other common proteins [59]. The high levels of arginine in walnuts have already been identified as a positive feature as arginine can be converted into nitric oxide, a potent vasodilator, which can inhibit platelet adhesion and aggregation [60]. A low ratio of lysine/arginine in a protein has been identified as a positive feature in the reduction of the development of atherosclerosis in laboratory animals [61].

2.1.5. Total carbohydrate

Carbohydrates are found in almost all living things and play a critical role in the proper functioning of the immune system, fertilization, pathogenesis, blood clotting, and human development. Total carbohydrate of walnut had been calculated by several authors by subtracting other nutrient contents from total weight. Edem *et al*. [33] studied some African walnut and obtained total carbohydrate content of 53.20%. This was however higher than the result obtained by Ayoola *et al.* [14] on Nigerian walnut, which was 19.96%. Study on walnut (*Juglans regia* L.) genotypes grown in Turkey showed total carbohydrate content of 8.05–13.23% [29], while Ali *et al.* [26] obtained total carbohydrate content between 8.04 and 12.14%.

2.2. Fatty acid composition of walnut

The fatty acid composition of walnut samples is especially important to human nutrition and biochemistry [29]. Most nuts are rich in mano unsaturated fatty acid (oleic acid) while walnuts are also high in two polyunsaturated fatty acids linoleic acid and α-linolenic acids [42]. The walnut fatty acid composition shows high contents of linoleic acid and linolenic acid which are beneficial to human health, and linoleic acid and especially linoleinic acid play important roles for human health regarding the cardio vascular system [12,29,46].

Studies in Italy and New Zealand have shown that the total fat and the individual fatty acid contents of different cultivars vary widely [62-63]. Researchers have identified that no differences in the total fat content or the individual fatty acid contents could be observed [29,62]. The linolenic acid contents of walnuts grown under the

same conditions in New Zealand ranged from 8.0 – 13.8% while the linolenic contents of walnuts grown in Italy ranged from 12.8 – 15.3% [58,62]. A later study [63] on a wider range of walnut cultivars confirmed that the total oil ranged from 64.2 to 68.9% and the linolenic acid content varied between 10.7and 16.2%. The study by Bayazit and Sumbul [4] indicated that the Palmitic acid values of some walnut genotypes were ranged from 6.98 to 8.77%, oleic acid ranged from 19.33 to 36.76%, linoleic acid ranged from 41.55 to59.89%, linolenic acid ranged from 8.44 to 11.0% and steraic acid ranged from 3.22 to 4.99%.

The main fatty acids identified by gas chromatography reported by Ozcan were palmtic (6.4 %) oleic (13.4 %), linoleic (55.3 %) and linolenic (8.7 %) acids [16]. Özkan and Koyuncu [29] presented the palmitic, stearic, oleic, linoleic and linolenic acid content of some walnut genotypes as 5.24 – 7.62 %, 2.56 – 3.67 %, 21.18 – 40.20 %, 43.94 – 60.12 % and 6.91 – 11.52 % respectively. Zwarts *et al.* [62] obtained similar result for palmitic acid (6.7 – 8. 2 %), stearic acid (1.4 – 2.5 %), oleic acid (13.8 – 33.0 %), linoleic (49.3 – 62.3 %) and linolenic acids (8.0 – 14.2 %).The oleic acid content of the walnuts studied by another worker ranged from 22.63 to27.27 % while the linoleic and linolenic acid contents ranged from 49.93 to 54.41 % and 14.32-17.82 %respectively. However, the palmitic acid content ranged from 5.61 % – 5.82 % [48].

Increased levels of linolenic acid in the diet have been associated with reduced risk of heart attacks in several prospective studies, possibly due to antithrombotic and antiarrhymic effects of a-linolenic acid [64-65]. Nuts have been shown as nutrient dense foods rich in unsaturated fatty acids and other nutritional compounds such as protein, carbohydrate, fiber and minerals. Nuts especially, walnut are highly beneficial to human health because of their unique composition [5,6,67].

2.3. Mineral composition of walnut

Walnut is considered a good source of dietary minerals. Potassium, phosphorus, magnesium and iron are found in significant quantities in these nuts. A number of research works have been conducted to find the content of nutritive elements in walnut and on their impact on human health [16,43]. Lavedrine *et al.,* [43] in studying the mineral composition in two walnut cultivars (‘Franquette’, ‘Hartley’) with origin in France and California, has found significant differences for three mineral elements (potassium, sodium, magnesium) depending on cultivar and origin. Walnuts (*Juglans regia* L.) are rich in valuable minerals like phosphorus, potassium, sodium, magnesium and zinc [43].

2.3.1. Sodium (Na)

Sodium is an important electrolyte and essential ion in the extra cellular fluid (ECF) plays a key role in enzyme functions and muscle contraction [67]. In addition, it is important for osmosis regulation and fluid maintenance of the human body. Other roles of sodium include heart performance, nervous system and glucose absorption. This element is also required for the operation of nerves and muscles, but an excess of sodium can damage the kidneys and increase the possibilities of hypertension [67]. Several authors have reported the presence of considerable quantities of Na in various genotypes of walnut including 44.7 mg/kg [16]; 166.5 mg/kg [27]; 617.7 –833.4 mg/kg [42], 906.64 mg/kg [55]. Thus, walnut consumption can serve as a means of Na intake to human. Furthermore, it is interesting to know that not only the kernel, but also the root of walnut contains essential minerals which could be useful for therapeutic purposes. Ayoola and co- workers studied walnut root samples from Ajaawa, Ogo-oluwa Local Government Area of Ogbomoso in Oyo State, Nigeria and obtained 0.105 mg/g (105mg/kg) of Na [13].

2.3.2. Potassium (K)

Potassium is an essential mineral that works to maintain the body’s water and acid balance. It plays a role in transmitting nerve impulses to muscles, in muscle contractions and in the maintenance of normal blood pressure [68]. This mineral is needed for keeping heart, brain, kidney, muscle tissues and other important organs of human body in good state. Potassium can be found in vegetables, fruits, potatoes, meat, bread, milk and nuts [67]. The biological roles of K are essential for disease prevention and control [69]. Ozcan *et al.* [42] determined 13 elements in some walnut types using inductively coupled plasma – atomic emission spectrometer (ICP-AES). Among other

elements determined, K concentration was 3478.8 mg/Kg. Çağlarırmak [55] reportedly sampled some walnut types and found the K concentration to be between 230 and 340 mg/100 g (2300 and 3400 mg/kg). A study by Ozcanon some walnut (*Juglans regia* L.) types growing in turkey revealed the mean potassium content of his samples to be 4627.6±34.7 mg/kg [16]. Another authors somewhere reported similar concentration of potassium in walnut samples they studied [27]. From the forgoing, it is seen that walnut is rich in minerals especially potassium.

2.3.3. Calcium (Ca)

Calcium is an essential nutrient that plays a vital role in neuromuscular function, many enzyme-mediated processes, blood clotting, and providing rigidity to the skeleton via phosphate salts. Its non-structural roles require the strict maintenance of ionized calcium concentration in tissue fluids at the expense of the skeleton if necessary, and it is therefore the skeleton which is at risk if the supply of calcium falls short of requirement [70]. The richest sources of calcium are dairy products. In countries where milk is scarce, calcium may be obtained from certain cereals (notably millets). Small saltwater and freshwater fish such as sardines and sprats supply good quantities of calcium since they are usually eaten whole, bones and all. Vegetables and pulses provide some calcium [68]. Calcium is also the major component of bone and assists in teeth development [72]. Ozcan *et al.* [42] sampled some walnut species and determined calcium concentration in the range of 2757.88 ± 10.44 – 2462.32 ± 76.75 mg/kg. The range was however higher than that obtained by Çağlarırmak [55], which was 67 – 105.5 mg/100 g (670 – 1055 mg/kg).

2.3.4. Magnesium (Mg)

In spite of the structural function of magnesium in the skeleton, it has many functions in muscles and soft tissues, such as a co-factor of many enzymes involved in energy metabolism, protein synthesis, RNA and DNA synthesis, and maintenance of the electrical potential of nerve tissues and cell membranes. Dietary deficiency of magnesium of a severity sufficient to provoke pathologic changes is rare [70]. Magnesium is widely distributed in plant and animal foods. Most green vegetables, legume seeds, peas, beans and nuts are rich in magnesium, as are also some shellfish, spices and soya flour. Ozcan *et al.* [42] have proved that walnut is rich in Mg from the research they conducted on some samples of walnut. They determined Mg content in the range of 4163.36 ± 368.28 to 5488.10 ± 218.07 mg/kg. This range is also higher than the Mg content of walnut samples analysed by Çağlarırmak [55], which ranged between 81 – 99 mg/100 g (810 – 990 mg/kg).

2.3.5. Iron (Fe)

Iron is needed for the synthesis of blood pigments, as well as for many other essential activities of cells [67]. The best food source of iron is animal offal, especially liver. Other animal products like red meat are also rich in iron. The levels in cereals and vegetables are generally low, with the exception of dark green vegetables, such as spinach, which are rich in iron [73]. The importance of Fe in maintaining good health and well being has long been recognized by nutritionists; meat is the food richest in Fe, the Fe form with the highest bioavailability [69]. Fe is an important element in hemoglobin, myoglobin, and a large number of enzymes; therefore it is an essential mineral in daily diet. About 30% of iron in human body is as the storage form or ferreting and just a small level is associated with blood transport protein transfer [27]. Ozcan [16] studied the elemental composition of walnuts from Turkey using ICP-AES. He obtained a mean Fe content of 32.4 ± 4.3 mg/kg. His value was higher the range obtained by him and other co-authors on several walnut types that ranged from 17.875 ± 1.252 – 21.815 ± 3.514 [42]. Also, Iranian walnut was found to be rich in Fe (355.3 mg/100 g) [27].

2.3.6. Copper (Cu)

Copper is an essential trace element for humans and a vital component of several enzymes. Its absorption depends on the amount ingested, its chemical form, and the composition of other dietary components such as zinc [67]. Drinking water has a significant contribution to dairy intake due to the use of domestic copper pipes. Offal, such as liver and kidney, contain high copper levels. Fish, fruits, cereals, nuts, and green vegetables are good sources of

copper, whereas meat and dairy products contain lower levels [74]. Copper is important for cellular defence and protection of the mucous membrane, antianaemic and essential for the formation of haemoglobin from iron [75]. *Tetracarpidium conophorum* is a good source of manganese and copper, two elements that are very useful to mankind. Manganese is used in the management of diabetes [33]. Ayoola *et al.* [13] reported that the result of mineral composition clearly shows that *Tetracarpidium conophorum* root contains rich source of mineral elements. Copper in walnut has been determined by Ozcan *et al.* [42] and Ozcan [16]. The former obtained a concentration in the range of 5.676 ± 1.099 to 9.333 ± 0.801 mg/kg, while the latter found a mean Cu content of 3.8 ± 2.2 mg/kg. Traces of Cu were also found in root samples of *Tetracarpidium conophorum* (African walnut) which values at 0.000087 mg/g (0.087 mg/kg) [13].

2.3.7. Zinc (Zn)

Zinc is an essential element in human nutrition; it is present in many important enzymes essential for metabolism. Zinc is present in most foods both of vegetable and of animal origin, but the richest sources tend to be protein-rich foods such as meat, seafoods and eggs [71]. Zinc stimulates the activity of vitamins, formation of red and white corpuscles [75], healthy functioning of the heart and normal growth [76]. Iranian walnut showed Zn concentration of 56.8 mg/100 g [27], while those from Turkey possessed mean concentration of 26.4 ± 3.2 mg/kg. In another instance, Ayoola *et al.* [13] have acknowledged that the presence of zinc in walnut root is an indication that the root may have some effect on the nerve function and male fertility. It is important for normal sexual development, especially for the development of testes and ovaries, it is also essential for reproduction. A study somewhere also reported Zn content of some walnut types in the range of 17.981 ± 0.523 to 20.623 ± 1.185 mg/kg [42].

2.3.8. Lead (Pb)

Humans have enjoyed lead's advantages and endured its harmful and sometimes devastating effects, virtually since the dawn of civilization [77]. Regulations governing uses and release into the environment have been instituted in many countries around the world. Roots usually contain more Pb than stems and leaves, while seeds and fruits have the lowest concentrations. Particulate Pb present in air may adhere tenaciously to leafy vegetables. Leaves collected in or very near to urban areas have been shown to contain substantially elevated concentrations of Pb. The major source of Pb for non-occupational exposed adults is food and beverage. Pb intoxication damages the nervous and hematopoietic system and may also result in dysfunction of renal tubules, liver, and cardiovascular system [78]. Children are particularly at risk from Pb consumption, both before and after birth. The proportion of total intake derived from food is dependent on the concentration of lead in air, water and other sources. Children are additionally exposed to Pb from dust and soil [77]. Pb has been tested and found to be capable of eliciting a positive response in an extraordinarily wide range of biological and biochemical tests. These tests have included measures of DNA synthesis, mutation and chromosome aberration, however Pb is considered to be a co-mutagen or a weak genotoxic agent [80]. Pb in no doubt will be contained in walnut, though several authors have not giving account of its content in walnut. Pb (0.69 – 1.06 ppm) composition of some walnut cultivars grown in Pakistan was described by Ali *et al.* [26].

2.4. Other compositions of walnut

2.4.1. Ascorbic acid (vitamin C)

Vitamin C can be used for the treatment of common cold and other diseases like prostate cancer [80-81]. Other vitamins though in trace amount are essential for body metabolism. There is also an interesting ability of ascorbic acid as an antioxidant, to prevent or at least minimize the formation of carcinogenic substances from dietary material [82]. Deficiency of ascorbic acid is associated with pains in the joint and defect in skeletal calcification, anaemia, manifestation of scurvy haemorrhage from mucous membrane of the mouth and gastrointestinal track [83]. Ayoola *et al.* [13] had stated that as a result of the presence of ascorbic acid in the root of walnut plant, they can be used in herbal medicine for the treatment of skin conditions, including eczema, pruritus, psoriasis and parasitic skin conditions [83]. High content of ascorbic acid also indicates that the plant can be used to prevent or at least

minimize the formation of carcinogenic substances from dietary material. It can also be used in treatment of indigestion, constipation and diarrhoea [13].

2.4.2. Tocopherols (vitamin E)

A large proportion of the fatty acids in walnuts are unsaturated and the oxidation of unsaturated lipid is linked to the appearance of unpleasant odours and flavours. The oxidation of the polyunsaturated fatty acids occurs slowly even in nuts stored in good conditions [2]. So nuts lose their excellent taste and their positive nutrition attributes if they are stored too long. The vitamin E isomers, which are present, provide some protection against oxidation of the unsaturated fatty acids. The measurement of vitamin E isomers is important due to their antioxidative and other positive nutritional effects in human metabolism. So far the measurement of these isomers in walnut oil has not been well documented. Lavedrine *et al.* [59] has presented some data on the vitamin E content of walnuts grown in France and the USA. They identified α, β and γ tocopherol in fresh and stored nuts and noted the significant losses that occurred after three months storage at 4°C. They identified γ tocopherol as the main tocopherol in walnut oil. The tocopherol content of New Zealand cultivars of walnuts ranges from 290 to 435 mg/g oil [84]. The New Zealand selected cultivar Rex had the lowest total vitamin E content while Dublin's Glory had the highest of all the cultivars [84]. The proportion of individual vitamin E isomers remained constant in all the nuts.

2.4.3. Alkaloids

Alkaloids are the most efficient plant substances used therapeutically. Pure isolated alkaloids and the synthetic derivatives are used as the basic medicinal agent because of their analgesic, antispasmodic and bacterial properties [14]. This is the reason walnut root is believed to stop asthma and is prescribed to be taken between bouts of asthma, but not for acute asthma, it's used for elderly as a constipation cure [13]. The presence of tannins in root of *Tetracarpidium conophorum* can support its strong use for healing of haemorrhoids, frost bite and varicose ulcers in herbal medicine [36-37]. The presence of phenolic compounds in the roots shows that the plant may have antimicrobial potential. This is because phenols and phenolic compounds have been extensively used in disinfections and remain the standards with which other bacteriocides are compared [85].

2.4.4. Sterols

Phytosterols have been regarded as cholesterol-lowering agents since the early 1950's [86]. Plant sterols appear to pass through the intestinal tract almost unabsorbed [87] but plant sterols also appear to interfere with the absorption of cholesterol, which is a very positive thing to do. Animal and human studies have shown that moderate intakes of dietary plant sterols decrease serum total cholesterol and LDL-cholesterol levels [88-90]. This effect appears to be due to inhibition of cholesterol absorption [91-92]. The levels of sterols found in walnuts may be enough to exert a positive effect on human metabolism but this depends on the amount of walnuts eaten on a regular basis. It is interesting to note that the levels found in different cultivars grown under similar conditions vary considerably [93]. This suggests that it may be possible to select some cultivars with more advantageous nutritional features than others.

2.4.5. Dietary fibre

Dietary fibre has important effects on conditions such as diabetes, hyperlipidemia and obesity and may have preventative implications for conditions such as hypertension, coronary heart disease and some intestinal disorders [61,94]. Although specific associations between dietary fibre and disease may be difficult to prove directly there are benefits in consuming foods rich in fibre. Nuts may protect against coronaryheart disease through a number of mechanisms [6,12]. Fibre is mentioned as one of the eight possible positive constituents of nuts [10]. The total dietary fibre content of 12 different cultivars of walnuts harvested in New Zealand ranged from 3.1 to 5.2 g/100g dry matter [57]. Lintas and Cappelloni [95] were able to identify both insoluble and soluble fibre using the Prosky method [96] in a range of nuts grown in Italy. Unfortunately they were unable to identify the different cultivars of

the nuts they had analyzed. The insoluble fibre content of the nuts they analyzed ranged from 15.8 g/100g for macadamia nuts to 3.8 g/100g for pine nuts. In contrast, the soluble fibre contents of nuts they analyzed appear to be quite low.

2.5. Therapeutic effects of walnut

Ripe walnuts are mostly eaten as dessert nuts or used in cakes, desserts and confectionery of all kinds from ice cream to Baklava. The walnut plant has a high nutritional value and high quality wood. In turkey, walnut has a special value in Turkish foods and is very common in traditional Turkish foods [16]. Walnut leaf is used for treating rheumatismal pains, fever, diabetes and cutaneous diseases; its root is used in treating diabetes, and walnut blossoms are used in treating malaria [97]. In addition, walnut leaf is extensively used in traditional medicine for treating headaches, frost bites and skin conditions. It lowers the risk of cardiovascular diseases and is helpful for haemorrhoids diarrhoea, fungal diseases, hypertension and elevated blood sugar [98-99]. It appears that treatment with walnut husk extract or other antioxidants may be helpful in suppressing oxidative stress and other injurious mechanisms. Walnuts are considered to be an herb in Traditional Chinese medicine. They aid proper functioning of the kidneys, strengthen the back and knees, moisten the intestines and move stool. It is believed to stop asthma and is prescribed to be taken between bouts of asthma, but not for acute asthma [13]. It is used for elderly as a constipation cure [32]. The bark is used in tea as laxative and chewed for toothache. It helps to prevent and control high blood pressure, the list is just endless.

3. Conclusion

Apart from its economic importance, the Nigerian Walnut (*Tetracarpidium conophorum),* is a vital plant with uncountable health benefits, since it has proven to contains considerable and useful amount of both macro and micro nutrient required for proper development and enhancement of organs and systems in living organisms. Proximate analyses performed by researchers have shown that the walnut contains an appreciable amount of unsaturated fatty acids, proteins, carbohydrate as well as great amount of fibre content, thereby making it nutritious to human when consumed. It is evident that the walnut also exhibits some great therapeutic properties, as discussed.

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