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Mineral and Vitamin Concentrations of Heat Processed *Plukenetia conophora* Seed Kernel Consumed in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Mineral and vitamin concentrations of heat processed *Plukenetia conophora* seed kernel consumed as snacks in Nigeria were investigated. The seeds which were obtained from Ojoto in Anambra State, Nigeria were washed in several changes of distilled water, divided into four lots - PC_{raw} (raw sample), PC_{45}, PC_{90} and PC_{135} (samples cooked for 45, 90 and 135min respectively), oven-dried and milled into flours. Concentrations of the minerals (Ca, K, Mg, Na, Pb, Cu, Fe, I and Mn) in PC_{raw} decreased as the time of cooking increased from 45min (PC_{45}) to 135min (PC_{135}), while for P, Zn and Se the concentrations increased over time of heat processing. The most abundant mineral was sodium (27.41mg/100g) followed by calcium (21.04mg/100g) and lowest in iodine (3.0µg/100g).

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Iodine was the most heat-labile mineral followed by iron and then lead. *Plukenetia conophora* seed kernel flours were found to be excellent sources of vitamins E, K, B_1, B_6 and B_9 and good sources of vitamins D, B_2, B_3, B_5 and thus the plant food is recommended for consumption sinceit could provide significant amount of the recommended daily allowance of these micronutrients for adults.

Keywords: Micronutrient concentrations; heat processing; Plukenetia conophora seed flour.

1. INTRODUCTION

Nutrients (in food) are needed by the body for generation of energy and for growth and maintenance. Vitamins and minerals are classes of nutrients required by the body in minute amount and are therefore called micronutrients. Micronutrients are essential in the maintenance of human health [1,2]. Minerals (inorganic substances) serve a variety of functions including the formation of bones and teeth; as essential constituents of body fluids and tissues, components of enzyme systems, nerve function. For microminerals the amount needed by the human body per day is less than 100mg while for macrominerals it is greater than 100mg. Vitamins are either fat- or water- soluble and are involved in the body's metabolism, cell production, tissue repair, and other vital processes.

Edible wild plants and fruits are exploited to provide supplementary nutrition in developing nations [3,4,5].

Studies have shown that many plant foods contain high amount of minerals, vitamins, fiber and phytochemicals that make them nutritionally important [6]. One of such plant foods is *Plukenetia conophora. P. conophora* (African walnut) a climbing and twining plant (Liane) over 30m long, is indigenous to Africa, especially West Africa. It is of the family *Euphorbiaceae* and is commonly known in Nigeria as "Ukpa" (Igbo), "Asala" or "Awusa" (Yoruba), "Okhue or Okwe" (Edo) [7,8]. The fruit is a capsule, 6-10cm long by 3-11cm wide containing sub-globular seeds 2 - 2.5cm long with a thin brown shell resembling the template walnut (Plate 1). The seed is eaten raw, roasted or cooked mainly as indigenous snacking nut (masticatory).

Plate 1. Photograph of *P. conophora* seeds

Heat processing has been reported to have the potential to alter the nutrient quality of foods [9,10,11,12]. This, according to Ebirien et al. [13] depends on the degree of processing and the nutrient in question.

Nutrients may be destroyed or lost when foods are processed because of their sensitivity to heat, light, oxygen, pH of the solvent or combinations of these [14].

Processing may also made nutrients more available through the release from entrapment in the plant's matrix [15] or reduction in the concentration of antinutritional factors inherent in the food [16,17,18]. Food processing method should therefore be such that does not adversely affect the colour, texture, flavor, nutritional values especially the vitamins and minerals [19]. This article is intended to evaluate the effect of heat processing on the mineral and vitamin concentrations of *P. conophora* seed kernel consumed in Nigeria.

2. MATERIALS AND METHODS

All reagents were obtained from Merch (Darmstadt, Germany) and used as such. Fresh fruit capsules of *P. conophora* were purchased from a farmer at Ojoto, Idemili South Local Government Area of Anambra State, Nigeria. The capsules were cut open with a sharp knife and the wholesome seeds collected.

2.1 Sample Processing

Wholesome samples were washed in several changes of distilled water and divided into four (4) lots. The first lot was used raw and therefore labeled PC_{raw}. Trial cooking using traditional cooking method(which involved boiling at 98±0.03ºC in an aluminum cooking pot with sufficient water) showed that accepted eaten tenderness was obtained 90min. The 2nd, 3rd and 4th lots were boiled in water (98±0.03^{o}C) for 45, 90, and 135 min and labelled PC_{45}, PC_{90}, and PC_{135} respectively. The shell of PC_{raw}, PC_{45}, PC_{90} and PC_{135} were cracked with a hammer and the kernels collected. The kernels were sliced thinly with a knife and dried for 48hr in an air-circulatory oven (50ºC) (Model OVE.100.130M.Gallenkamp, UK). The oven-dried samples were groundin a mill (Model BL357. Kenwood, Birmingham UK), passed through a 60-mess size screenand used in the analyses.

2.1.1 Mineral content analyses of the samples

The mineral content of the samples were determined by the use of Atomic absorption spectrophotometry [20] as described by Onyeike and Acheru [21].

Three grams of the stock sample was incinerated in a muffle furnace (Model AAF 11/7, Cabolite, Derbyshire, UK) at 550ºC until ash was obtained. The non-combustible inorganic mineral contents of the ash were extracted with 20ml of 2.5%HCl. The extract was reduced to 8.0ml by heating in a water-bath (98±0.03ºC) for 1hr, diluted to 50ml with deionized water and stored in clean polyethylene sample bottle.

The mineral contents were determined using atomic absorption spectrophotometer (Model 2380, Perkin-Elmer, USA).

The instrument was calibrated with standard solution containing known amounts of the minerals being estimated. The results were expressed in mg per 100g sample.

2.2 Vitamin Analysis

The modified AOAC [22] method 992.03, 992.04 and 992.26(Codex-Adopted-AOAC Method) for vitamin analysis was used. This involved the gas chromatographic analyses of the vitamin contents of the sample extract using HP5890 powered with HP ChemStation Rev.A09.01 (1206) software (Hewlett-Packard, California, USA).

The sample was pressed in a mortar carefully to avoid forming lumps. A 0.1g of the sample and 0.05g ascorbic acid (as antioxidant, to reduce oxidation reactions that could affect vitamins during saponification and extraction) were weighed into 16x126mm test tube and 5ml of alcohol (made by mixing 90.2% ethanol, 4.9% methanol, and 4.9% isopropanol) and 0.5ml of 80% KOH(w/v) were added and the tube vortexed for 30sec. The alcohol was needed to stabilize the saponification solution and prevent the precipitation of soap material [23]. Then, the test tube was flushed with nitrogen gas(N_2) and capped (to reduce vitamin loss to oxidation), and incubated for 30min in a water-bath (70^{o}C) with periodic vortexing. The tube was then placed in an ice bath for 5min to reduce the solubility of interfering substances [24].

Deionized water (3ml) and 5ml of hexane were added to the test tube, vortexed for 30sec, and then centrifuged at 1000xg for 10min. The upper hexane layer was transferred to another test tube and the residue re-extracted two more times, each with 5ml hexane. The pooled extract was concentrated to 1ml by evapouration under N_2 flow.

The concentrated extract was analyzed for vitamin contents in a HP Gas chromatograph (Model 5890, Hewlett-Packard, USA) powered with HP ChemStation Rev.A09.01 (1206) Software. The GC was calibrated with selected standards.

The gas chromatography conditions for the analysis of vitamins were as stated below.

The injection temperature was split while split ratio was 2:1. Carrier gas was nitrogen with inlet temperature of 250ºC in a HP5 column type of dimension 30x0.25mmx0.25µm. The oven was programmed to give initial temperature of 50ºC, first ramping at 10ºC/min for 20min maintained for 4min and second ramping at 15ºC/min for 4min maintained for 2min.The detector used was pulsed flame-photometric detector (PFPD) at 320ºC with hydrogen and compressed air pressures of 20psi and 30psi respectively.

From the chromatogram of the sample extract and that of the mixture of standards produced by the GC, the vitamin contents of the sample were identified and quantified by an enhanced integrator which gave the result as mg/100g sample.

3. RESULTS AND DISCUSSION

The mineral contents of raw and cooked samples of *P. conophora* seed flours are presented in Table 1.

Concentrations of Ca, K, Mg, Na, Pb, Cu, Fe, I and Mn decreased with increasing processing time. Ebuehi [25] reported that boiling brings about losses of some minerals. However, P, Zn and Se increased as time of heat processing increased. Adeniyan et al. [18] reported that while the concentrations of some minerals were reduced others were increased by boiling. Earlier, Severi et al. [9] reported that cooking resulted in losses of vitamins and minerals.

Table 1. Mineral concentrations[a] of raw and cooked *P. conophora* seed flour

Mineral	Samples			
	PC_{raw}	PC_{45}	PC_{90}	PC_{135}
Ca(mg/100g)	21.04	20.20	18.83	10.77
K(mg/100g)	8.97	6.52	4.75	3.63
Mg(mg/100g)	7.03	5.07	5.06	5.02
Na(mg/100g)	27.41	20.63	17.08	5.0
P(μg/100g)	17.0	22.0	24.0	22.0
Pb(μg/100g)	10.0	10.0	6.0	NDL
Cu(μg/100g)	560.0	450.0	450.0	440.0
Fe(mg/100g)	2.26	0.77	NDL	NDL
I(μg/100g)	3.0	NDL	NDL	NDL
Mn(mg/100g)	2.40	1.99	1.97	1.68
Zn(mg/100g)	2.47	2.56	2.76	2.62
Se(μg/100g)	4.89	7.61	8.0	10.35

[a]*Values are means of duplicate determinations on dry matter basis. NDL = non-detectable level*

While the value for Se increased from PC_{raw} to PC_{135}, those of P and Zn were maximum at PC_{90}. The percentage differences between the mineral contents of raw and cooked samples areshown in Table 2.

Table 2. Differences in mineral concentrations between raw and cooked *P. conophora* seed flour

Mineral	[a] Differences (percentage difference)		
	PC_{raw}- PC_{45}	PC_{raw}- PC_{90}	PC_{raw}-PC_{135}
Ca	0.84(3.99)	2.21(10.50)	10.27(48.80)
K	2.45(27.31)	4.22(47.10)	5.34(59.53)
Mg	1.96(27.88)	1.97(28.02)	2.01(28.59)
Na	6.78(24.74)	10.33(37.69)	22.41(81.76)
P	-5.0(29.41)	-7.0(41.18)	-5.0(29.41)
Pb	0.0	4(40.0)	10.0(100)
Cu	110.0(19.64)	110.0(19.64)	120.0(21.43)
Fe	1.49(65.93)	2.26(100)	2.26(100)
I	3.0(100)	3.0(100)	3.0(100)
Mn	0.41(17.08)	0.43(17.92)	0.72(30.0)
Zn	-0.09(3.64)	-0.29(11.74)	-0.15(6.07)
Se	-2.72(55.62)	-3.11(63.6)	-5.46(111.7)

[a]*Negative sign indicates increase in value*

Na was the most abundant mineral in the raw and sample cooked for 45min followed by Ca and then K. The abundance of Ca, P and K in plants has been reported by Canellas and Saura-Calixto [26]. The mineral with the lowest concentration was iodine in the raw sample (PCraw), Se in PC_{45} and PC_{135} and, Pb in PC_{90}.

Iodine was reduced beyond detectable level at PC_{45}, Fe at PC_{90}, and Pb at PC_{135}.The level of the effect of cooking depends on the processing time and the mineral in question as earlier reported by Ebirien et al. [13]. At 45 min of heat processing, iodine was the most susceptible being reduced by almost 100% followed by Fe (65.93%) and then Se (55.62%), and Zn (3.64%).

At 90 min, iron was the most affected (100%) followed by Se (63.60%) and then K (47.1%) while selenium (111.66%) became the most susceptible at 135min followed by Pb (100%) and then Na (81.76%).Osum et al. [27] and Adeniyan et al. [18] also reported reduction in the Na content of *Vitex doniana* (black plum) leaf by blanching and *Sesamum indicum* (beniseed) by boiling respectively. The observed range for the sample was comparable with the value 10.4mg/100g obtained for the fruit pulp of black plum by Vunchi et al. [28]. The recommended daily allowance (RDA) of Na for adult is 1000-13000mg [29]. It follows that 1kg of the sample could supply 27.44-17.0% of the RDA of Na for adult if not cooked for more than 90min. Na is an essential element which in conjunction with K works for extracellular fluid balances and normal osmotic pressure in the body, and in nerve transmission [30,28,31,32].

Na/K ratio is of significance especially to a hypertensive patient [2]. A ratio of less than one has been recommended for the prevention of high blood pressure [33]. The ratio obtained in this work at all levels of processing is above 3. The consumption of the plant food is therefore not recommendable for hypertensive patients.

K has been shown to play protective role against hypertension, stroke, cardiac dysfunctions, renal damage, hypercalciuria, kidney stones and osteoporosis [34]. The RDA for K is 4700mg for adult. The K content of the *P. conophora* sample was reduced from 8.97-3.63mg/100g by cooking. Adeniyan et al. [18] also reported that cooking progressively reduced the K content of *Sesamum inducum.* The sample investigated is a poor source of dietary K as 1kg could not supply up to 2% of the RDA for adult.

On the other hand the plant could be adjudged a good source of Mg as 1kg could supply at least 15.69-21.97% of the 320-420mg RDA of Mg for adults[29]. Mg content of the sample was reduced at all levels of processing given the range 5.02-7.03mg/100g. This value was higher than the values 1.80-2.00mg/100g reported for African bread fruit by Ijeh et al. [35]. Mg is an important mineral element and is implicated in circulatory diseases [2,36]. It is involved in the maintenance of the electrical potential of nerves and cell membranes and, activation of many enzyme systems [37,38]. It also functions as a co-factor for many enzymes in energy metabolism and biosynthesis of macromolecules [35].

P in the raw sample (17.0µg/100g) was made more available by heat processing. Adeniyan et al. [18] also showed that P content of beniseed increased progressively with boiling time. These contradicted earlier reports that boiling reduced the phosphorous content of yellow yam [11] and red kidney bean [33]. P helps to control the acid-alkaline state of the blood [39]. In association with Ca, P is involved in blood formation and, bone, teeth and muscle growth and maintenance [40,4]. P is also a component of nucleotide molecules that are structural components of the nucleic acids, DNA and RNA and of the energy transfer molecules such as ATP, NAD, and FAD. Based on the RDA of P of 500mg for adults [11], *P. conophora* is not a good source of dietary P.

Ca level was decreased by cooking. Akin-Idowu et al. [11] and Adeniyan et al. [18] earlier reported that Ca content of yam and beniseed increased with boiling time. When cooked to tenderness (PC90), the concentration of Ca was highest (18.83mg/100g).

The observed range of concentration of calcium 10.77-21.04mg/100g compared favourably with the range 10.2-23.1mg/100g obtained for cashew nut [41, 39]. *P. conophora* could be adjudged a good source of Casince 1kg of the sample could supply 13.46-26.3% of the 800mg RDA of Ca for adults [11,42]. Over 99% of Ca in the body is used as structural components of bones and teeth [43,27]. Ca participates in many enzyme-mediated processes [41,28] and is involved in nerve conduction, aids muscle growth and prevents muscle clamps [38]. Intestinal Ca absorption is governed by Ca/P ratio of the diet. A ratio of more than one indicates the diet as "good" as more Ca would be absorbed [44,28,33]. At 45 min cooking, 65.93% of the 2.26mg/100g iron in theraw sample was lost leaving 0.77g/100g which is lost completely when cooked to eaten tenderness. The plant food is a good source of Fe but must be eaten raw or undercooked to contribute 9.63-28.25% of the 8mg RDA [28] per 100g sample. Fe is an essential trace element required for haemoglobin formation, normal function of central nervous system and energy metabolism [45, 46].

P. conophora is an excellent source of dietary copper as 100g could supply 48.89-62.22% of the 900µg RDA [28]. Cooking decreased the Cu content of the sample giving the range 440.0-560.0µg/100g. Reduction was also reported by Musa and Ogbadoyi [32] for *Hibiscus sabdariffa*. Earlier Ijeh et al. [35] reported that processing made copper more available in cashew nut giving the range as 350-400µg/100g. Like Fe, copper is a component of haemoglobin and participate in blood function [39].

Mn was progressively decreased (17.08-30%) by cooking giving the range 1.68-2.40mg/100g. Adeniji and Tenkuano [47] and Audu and Aremu [33] also reported reduction on Mn contents of plantain-banana hybrid and red kidney beans respectively. The observed values for *P. conophora* compared favourably with the values 1.6-1.7mg/100g obtained for red kidney beans. The Mn content of the raw sample (2.40mg/100g) compared very well with the value (2.20mg/100g) obtained by Ayoola et al. [48] for air-dried fresh *C. conophora* sample obtained from Oyo State, Nigeria. The concentrations of other minerals in this study were tremendously lower than the corresponding values obtained by the researchers.The sample investigated is an excellent source of Mn as 100g could supply the 1.2-3.2mg RDA for adult [29] at all levels of processing. Mn is an activator of many enzymes [49] and a component of the bone which functions in reproduction and actions of the CNS [50].

Processing increased the zinc content of the sample by 3.64-11.74%. The sample is a good source for dietary Zn as 100g could supply 30.9-34.5% of the 8-11mg RDA for Zn [29]. Zn is important in the absorption and action of B-complex vitamins and inhibits 5-alpha reductase from converting testosterone into dihydrotestosterone (DHT), a form of testosterone that promotes prostate growth. Zinc increases testosterone, and sperm count. In zinc deficiency, sex drive is reduced in order to conserve the zinc (zinc is concentrated in semen) [51]. Zn is also involved in gene expression, regulation of cellular growth and acts as cofactor for enzymes responsible for carbohydrate, protein and nucleic acid metabolism [52]. It plays important role in the metabolism of cholesterol, heart disease and diabetes [53,54].

Iodine was the most heat-labile element in the sample. The 3.0µg/100g concentration in the raw sample reduced to non-detectable level at 45min cooking. The trace element is required by the developing foetus due to its effect on brain development and is required for the synthesis of thyroid hormones [55,35]. The sample is not a source of dietary iodine. On the other hand, the Se content of 4.89-10.35µg/100g could supply 23.76-51.24% of the 20.2-26.2µg RDA for Se [56,35] and was increased by cooking.

Higgs et al. [57] reported that Se content of oat and wheat were increased by boiling but reduced to non-detectable level when the boiling time was beyond 45min. Most of the selenium in the body is found in proteins as seleno-analogues of sulphur amino acids. Se is an antioxidant that protects vitamin E from degradation and is involved in the maintenance of defense against infections and modulation of growth and development [58,59]. Two selenium-containing enzymes (selenoenzymes) glutathione peroxidases and thioredoxin reductases (Endogenous antioxidants) are involved in the protection of the body tissues against oxidative damage by the highly reactive oxygen-containing metabolites (hydrogen peroxide or lipid hydroperoxide) [60].

The lead content of the raw sample (10.0µg/100g) was not affected by cooking for 45min, but decreased to non-detectable level at 135min. Audu and Aremu [33] reported 10µg/100g for red kidney bean and that the value dropped to non-detectable level with boiling. Lead is ubiquitous in the environment and thus present (at very low levels) in all foods. The observed value may be site-specific relating to the extent of lead pollution of the sample area [61]. Lead is very toxic when accumulated in the body and can lead to death [62,31]. The daily permissible amount of lead for adult is about 232.14µg [63]. With 1kg of the sample supplying at most 100µg of lead, the plant food is safe for consumption at all levels of processing.

Tables 3 and 4 respectively represent the fat-soluble and water-soluble vitamin levels for raw and cooked samples of *P. conophora*. The data showed that the most abundant fat-soluble vitamin in the plant food at all levels of processing was vitamin E while the lowest concentration was obtained in vitamin D_3.

Table 3. Concentrations[a] of Fat-soluble Vitamins in raw and cooked *P. conophora* seed flours

Vitamin	Samples			
	PC_{raw}	PC_{45}	PC_{90}	PC_{135}
A(µg/100g)	6.76	6.87	7.76	6.87
D_1(IU/100g)	0.46	0.55	0.52	0.47
D_3(IU/100g)	0.13	0.14	0.15	0.13
E(mg/100g)	0.74	0.75	0.75	0.75
K (µg/100g)	29.87	30.23	32.52	32.57

[a]*Values are means of duplicate determinations on dry matter basis*

The water-soluble vitamin with the highest concentration was niacin (Vit. B_3) and Choline (Vit.B_4) the lowest.

Heat processing (cooking) generally increased values of the fat-soluble and water-soluble vitamins.Similar results have been reported for vitamins A and D_3 in raw English walnut and soybean [64,65].

The concentration of vitamin K (Table 5) increased with increase in cooking time from PC_{raw} – PC_{135} giving a range of 29.87 - 32.57µg/100g (i.e. 1.21 – 9.04%). This is higher than the values of 0.3µg/100g and 2.7µg/100g obtained for egg and English walnut respectively [64].

One kg of the sample when processed to acceptable cooking tenderness (PC_{90}) could supply 15.5-7.76% of 500-100µg RDA for vit. A 15-30% of 5-10µg RDA for vit.D, 75-107.14% of 7-10mg RDA for vit.E and, 50.03-162.6% of the RDA for Vit.K for children and adult [42,11]. Vitamins E, K and A are essential nutrients [66]. Vitamin E, through its antioxidant property mops up excess free radicals produced in the tissues and thus controls the development of oxidative stress - induced diseases [67]. Vit. K functions as cofactor in the enzyme system that forms native prothrombin involved in the haemostatic (styptic) coagulation [68]. Vitamin A on the other hand, is required in small amount by humans for normal functioning of the visual system and its deficiency leads to xerophthalmia, anaemia, and weakened resistance to infection [27]. As reported by WHO [69], Vit. A deficiency affect about 2.5million pre-school children in Africa. Consequently, the consumption of the kernel is highly recommendable. Vit. A is also involved in the maintenance of growth, development and soundness of cells, epithelial cellular integrity, immune function and reproduction [70]. Vitamin D through its regulatory effect on the transcription of a number of genes is involved in Ca and P metabolism and, in the modulation of cell proliferation and differentiation [70]. From the comparison with the RDA, a properly processed sample of *P. conophora* seed could be adjudged a moderate source for vitamins A and an excellent source for vitamins E and K. The consumption of the seed kernel is therefore recommended for the prevention and management of cellular diseases, haemophilia, and visual system dysfunction and, general wellbeing.

Table 4. Concentrations[a] of water-soluble vitamins in raw and cooked *P. conophora* seed flours

Vitamin	Samples			
	PC_{raw}	PC_{45}	PC_{90}	PC_{135}
Thiamine,B_1 (mg/100g)	0.35	0.37	0.35	0.32
Riboflavin,B_2 (mg/100g)	0.14	0.15	0.15	0.14
Niacin,B_3 (mg/100g)	1.13	1.23	1.24	1.27
Choline,B_4 (µg/100g)	0.87	0.85	0.83	0.82
Pantothenate,B_5 (mg/100g)	0.52	0.53	0.53	0.51
Pyridoxine,B_6 (mg/100g)	0.45	0.48	0.45	0.43
Folate,B_9 (µg/100g)	94.76	82.45	76.37	74.22
Ascobate, C (mg/100g)	0.15	0.15	0.15	0.14

[a]*Values are means of duplicate determinations on dry matter basis*

Table 5. Difference in fat-soluble vitamins contents between raw and cooked *P. conophora* seed flours

Vitamin	[a]Differences (percentage differences)		
	PCraw – PC_{45}	PC_{raw} – PC_{90}	PC_{raw} – PC_{135}
A	-0.11(1.63)	-1.0(14.79)	-0.11(1.63)
D_1	-0.09(19.57)	-0.06(13.04)	-0.01(2.17)
D_3	-0.01(7.69)	-0.02(15.39)	0.00
E	-0.01(1.35)	-0.01(1.35)	-0.01(1.35)
K	-0.36(1.21)	-2.65(8.87)	-2.70(9.04)

[a]*Negative sign indicates increase in value*

The most abundant water-soluble vitamin, niacinas shown in Table 6 was progressively increased (8.85-12.39%) by cooking given the value 1.13-1.27mg/100g. The lowest concentrated, choline, together with folate was steadily reduced by cooking giving the values 0.82-0.87µg/100g and 74.22-94.76µg/100g respectively from PC_{raw} to PC_{135}. Choline, though not a vitamin by FDA definition, is a vital nutrient of B-complex vitamins needed for proper functioning of the nervous system, muscle movement, brain function and maintenance of cell membrane integrity [65]. It also regulates liver function and is necessary for normal fat metabolism. Folate recorded 12.99-21.68% reduction (Table 6) to be the most sensitive water-soluble vitamin in the sample. The observed value for folate compared closely with 77µg/100g obtained for egg [64].

Table 6. [a]Differences in water-soluble vitamins contents between rawand cooked *P. conophora* seed flour

Vitamin	Difference (percentage difference)		
	$PC_{raw} – PC_{45}$	$PC_{raw} – PC_{90}$	$PC_{raw} – PC_{135}$
Thiamine,B_1	-0.02(5.71)	0.00	0.03(8.57)
Riboflavin,B_2	-0.01(7.14)	-0.01(7.14)	0.00
Niacin,B_3	-0.10(8.85)	-0.11(9.74)	-0.14(12.39)
Choline,B_4	0.02(2.30)	0.04(4.60)	0.04(5.75)
Pantothenate,B_5	-0.01(1.92)	-0.1(1.92)	0.01(1.92)
Pyridoxine,B_6	-0.03(6.67)	0.00	0.02(4.44)
Folate,B_9	12.31(12.99)	18.39(19.41)	20.54(21.68)
Ascobate,C	0.00	0.00	0.01(6.67)

[a]*Negativesign indicates increase in value*

The concentrations of thiamine, riboflavin, pantothenate and pyridoxine increased when cooked for 45min. Ayoola et al. [48] could not detect pantothenate, pyridoxine and folate in their sample. Apart from ascorbate (4.15mg/100g) the values for vitE (0.12mg/100g), thiamine (0.06µg/100g), riboflavin (0.02µg/100g) and niacin (0.05µg/100g) obtained by Ayoola et al. [48] for air-dried *C. conophora* sample were far lower than the corresponding values obtained in this study. The observed levels of thiamine and pyridoxine are comparable to the values 0.341 and 0.537mg/100g obtained for English walnut [64]. Thiamine, riboflavin and pyridoxine principally function in macronutrient metabolism [27]. Ascobic acid content of the sample was reduced (6.67%) only when cooked for 135min (Table 4). Ascobate is a dietary antioxidant acting as an electron donor for eight enzymes in humans [71]. It prevents the formation of the potential mutagen N-nitroso compounds in the stomach and thus reduces the risk of gastric cancer [72,73]. It is involved in protein metabolism and collagen synthesis [28].

B-vitamins generally help the body to use energy-yielding nutrients such as carbohydrate, fat and protein for fuel [74]. They are also involved in red blood cell formation and, cell multiplication through their role in DNA replication.

Most nutrients in plant food are entrapped in the plant matrix and therefore not easily accessible [15]. Some nutrients are also made unavailable to the consumer through the formation of insoluble complex with antinutrients [75]. The observed increase in nutrient content of the food sample due to cooking could be attributable to the fact that cooking, a hydrothermal process may have disrupted the cell structure and membrane partitions of the seeds and caused the release of minerals and vitamins, and also antinutrients from entrapment in the plant matrix. The heat involved in cooking may also have caused the destruction/inactivation of antinutrients making available the nutrients that are trapped in complex formation [76,17,18]. The level of the antinutrients could also be reduced (increasing nutrient availability) through leaching of soluble ones into the processing water when the epidermal layers of the seeds are ruptured by heat processing [16]. The decreased effect of cooking on minerals and vitamins could be attributed to leaching (extraction) of the micronutrients into the processing water [77]. The leaching may be enhanced by the heat of processing which increases the solubility of most of the nutrients [74]. Decreasing effect may also be due to oxidation and thermal destruction of the micronutrients especially vitamins [78,79,80,27].

4. CONCLUSION

It can be concluded that cooking influenced the concentrations of all the minerals and vitamins in the food samples investigated. The effect depended on the micronutrient and duration of cooking. The plant food (sample) is an excellent source of vitamins E, K, B_1,B_6, and B_9 but good source of vitamins D, B_2, B_3, and B_5.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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