Advances in Research
2(11): 605-617, 2014, Article no. AIR.2014.11.004

SCIENCEDOMAIN *international*
www.sciencedomain.org

Effect of Maceration Time on Micronutrient Concentrations of *Canarium schweinfurthii* Pulp Flour

Michael O. Monanu[1], Ernest A. Anyalogbu[2*] and Eugene N. Onyeike[1]

[1]Department of Biochemistry, Nutrition and Toxicology Unit, Faculty of Chemical Sciences, College of Natural and Applied Sciences, University of Port Harcourt, Port Harcourt, Nigeria.
[2]Department of Biotechnology, School Science, Federal University of Technology, Owerri, Nigeria.

Authors' contributions

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

Original Research Article

Received 14th January 2014
Accepted 14th April 2014
Published 25th June 2014

ABSTRACT

The effect of wet heat-processing on the micronutrient composition of *Canarium schweinfurthii* (CS) pulps eaten as traditional snack in most parts of Nigeria was investigated. Fresh wholesome seeds of *C. schweinfurthii,* obtained from Aba (Abia State, Nigeria) were washed in several changes of distilled water and divided into four lots. The first lot was used raw (CS_{raw}) and the 2nd, 3rd and 4th macerated in water (55ºC) for 15, 30 and 45min to obtain CS_{15}, CS_{30} and CS_{45} respectively. CS_{30} represents sample traditionally processed to accepted cooking tenderness. The raw and wet-heat treated seed pulps, dried for 48hr in air-circulatory oven (50ºC) and milled into flours were evaluated for vitamin and mineral contents using standard methods. The mineral and vitamin contents of the plant food were affected by the processing method. There were progressive increase in the concentrations of Ca, Na, P, Zn, and Pb; and decrease in those of Fe, I, K and Mg as maceration time was increased. The concentrations of Cu, Mn and Se were increased to their peak values and then reduced as the processing time was extended. Highest values were obtained (per 100g sample) for Fe (7.78mg), I (12.0µg), K (11.34mg) and Mg (8.37mg) in CS_{raw}; Ca (21.41mg), Cu (289.33µg) and Mn (4.76mg) in CS_{15}; Na (23.36mg), Se (8.0µg) and Pb (122.67µg) in CS_{30} and; P (21.33µg) and Zn (1.79mg) in CS_{45}. Vitamins C (2.37mg/100g) and E (1.97mg/100g) were the most

**Corresponding author: E-mail: anyalogbu@yahoo.com;*

abundant vitamins in the sample. The concentrations of all the vitamins investigated increased to their respective peaks values at 15min maceration (CS_{15}) and then, with exception of thiamine, reduced with the extension of the processing time to 45min. It can be concluded that maceration for 15-30mins improves the micronutrient contents of CS pulp.

Keywords: Maceration; minerals; vitamins; processing; fat-soluble; masticatory; gas chromatographic.

1. INTRODUCTION

Nutrients are substances that must be consumed as part of the diet to provide sources of energy and materials for growth and maintenance [1,2]. Micronutrients are nutrients (vitamins and minerals) needed in minuscle (milligram or microgram) amount [2]. They enable the body to produce enzymes, hormones and other substances essential for proper growth and development. According to Kader et al. [3] and, Agbaire and Emoyan [4], fruits and seeds are important food sources from prehistoric times and are among the most nutritionally concentrated of human foods being high in nutrients (proteins, oil, energy, minerals and vitamins) and non-nutrients, important to human health. The seed pulps of *C. schweinfurthii* are among the widely consumed masticatories in Nigeria [5].

C. schweinfurthii (African elemi or bush candle) is a large evergreen tree with a long, clean, straight and cylindrical bole exceeding 50m. It is locally known in Nigeria as; 'Ube mgba' (Igbo), 'Atili' (Hausa) or 'Origbo' (Yoruba). As shown in Plate 1, the fruit is a drupe containing a single triangular shaped seed surrounded by a delicious purplish green pulp [6].

Plate 1. *C. schweinfurthii* fruits

C. schweinfurthii seed is macerated in hot water and the pulp eaten as snacking item in most parts of Nigeria. According to Severi et al. [1], FAO [7] and Audrey et al. [8] food processing has the potential to alter the nutrient quality of foods. Maceration, a hydrothermal processing [9], may enhance [10,11] or, reduce [12] the availability of micronutrients in plant foods.

This present study is intended to determine the effect of processing time on the vitamins and minerals contents of *C. schweinfurthii* pulp eaten as traditional snack in some parts of Nigeria.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Fresh fruits of *Canarium schweinfurthii* (CS) purchased from Ngwa road market in Aba, Aba South Local Government Area of Abia State, Nigeria were used in the analyses. Forty wholesome fruits were washed in several changes of distilled water and divided into four lots. The first lot was used raw and labelledCS_{raw}. Trial processing showed that eaten tenderness was obtained by macerating the CS fruits in hot water (55ºC) for 30 min.

The 2^{nd}, 3^{rd} and 4^{th} lots of the *C. schweinfurthii* fruits were macerated (by putting in hot water flask, adding sufficient water (55^oC) to cover them and the flask covered) for 15, 30 and 45 min and labelled CS_{15}, CS_{30} and CS_{45} respectively. The water was drained off and the fruit pulps scrapped from the stone, sliced thinly with a knife and dried for 48 hr in an air-circulatory oven (50^oC) (Universalwärmeschrank, UNB 100). The oven-dried samples were ground in a mill (Kenwood BL357), passed through a 60-mess size screenand used in the analyses.

All the analyses were carried out in duplicate determinations.

2.2 Mineral Content Analyses of Samples

The mineral (Ca, K, Mg, Na, P, Pb, Cu, Fe, I, Mn, Zn, and Se) contents of the samples were determined using Atomic absorption spectrophotometric method [13] described by Onyeike and Acheru [14].

Three grams of the dried sample was incinerated in a muffle furnace at 550ºC until ash of constant weight 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, diluted to 50ml with deionized water and stored in clean polyethylene sample bottle.

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

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

2.3 Vitamin Analysis

2.3.1 Fat-soluble vitamins (fsv): vitamins A, D1, D3, E, K

The modified AOAC method 992.03, 992.04 and 992.26(Codex-Adopted-AOAC Method) [15] for vitamin analysis was used. This involved the gas chromatographic analyses of the fsv contents of the sample extract using HP 5890 Powered with HP Chem Station Rev. A09.01 (1206) software (Hewlett-Packard, California, USA).

2.3.1.1 Procedure

A 0.1g of the sample and 0.05g ascorbic acid (as antioxidant) were weighed into 16x126mm test tube and 5ml of reagent 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 30 sec. The test tube was then flushed with $N_{2,}$ capped, and incubated for 30min in a water bath (70ºC) with periodic vortexing. The tube was then placed in an ice bath for 5 min.

Deionized water (3ml) and 5ml of hexane were added to the test tube, vortexed for 30 sec, and then centrifuged at 1000xg for 10 min. 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 (in a water bath) under N_2 flow.

The concentrated extract was analyzed for fsv contents under standard conditions in a HP Gas chromatograph (Model 5890) powered with HP ChemStation Rev. A09.01 (1206) Software calibrated with selected standards.

From the chromatograms of the extract and mixture of standards (VIT-FSK-R2-SET, AccuStandard, USA) the vitamin contents of the sample were identified and quantified by an enhanced integrator which gave the result as mg/100g sample.

2.3.2 Water-soluble vitamins (wsv): B1, B2, B3, B5, B6, B9, and C

The method developed by Santos et al. [16] was used. This involved the extraction of the wsv and their subsequent liquid chromatographic analyses using HPLC-MS/MS.

2.3.2.1 Procedure

A 0.250g of the sample and 0.05g of 0.1% BHT (as antioxidant) were weighed into 16 x 126mm test tube, 16ml of 10mM ammonium acetate/methanol 50:50(v/v) added and the test tube vortexed for 15min to extract the wsv. The test tube was then flushed with nitrogen, capped, incubated for 15min in an ultrasound bath (25ºC) and centrifuged at 14000g for 15min. The supernatant was withdrawn and filtered through a 0.45µm nylon filter. One millilitre of the supernatant was concentrated by evaporation of the methanol under a nitrogen stream. A 10µL of the concentrated wsv extract was then injected in a HPLC-MS/MS system; an Accela liquid chromatograph (P/N 60057-60020, Thermo Scientific, USA) equipped with a diode array detector (DAD-3000RS, Thermo Scientific, USA) and coupled to a MS analyzer via an electrospray interface (ESI). The selected reaction monitoring (SRM) parameters were optimized by direct injection of wsv standards (VIT-WSK-R1-SET) purchased from AccuStandard, USA. The vitamin contents of the extract were analyzed under standard conditions andthe result given in mg/100g sample.

3. RESULTS AND DISCUSSION

The mineral concentrations of raw and macerated *Canarium schweinfurthii* (CS) are shown in Table 1. The concentrations of all the minerals investigated were affected by the processing method. The magnitude of these effect, presented as percentage difference between the level of the mineral in the raw and processed samples are shown in Table 2. The values for P and Zn increased progressively with the processing time while those of K, Mg, Fe and I steadily decreased. Ca content was increased to the highest value (55.71%) at 15min maceration and then dropped to 21.75% at 45min given the range 13.75 - 21.41mg/100g. Copper and manganese levels which increased to their highest values at 15min maceration decreased through CS_{30} to the lowest values at $CS_{45.}$ The concentrations of Na and Pb were increased given maximum values at $CS_{30.}$ The value of 5.33µg obtained for selenium in the raw sample (CS_{raw}) was increased to the highest value of 8.00µ/100g (50.94%) when macerated for 30min (CS_{30}) and then reduced to 2.0µg/100g (62.48%) at 45min processing (CS_{45}).

The predominance of Ca, K and Mg in the sample (Table 1) agreed with earlier report by Canellas and Saura-Calixto [17] that these represent the most abundant metal constituents of plants. The abundance of K in agricultural product was also reported by Aremu et al. [18]; Aremu et al. [19]. In agreement with the results, Eke-Ejiofor et al. [20] observed increased Ca content in both boiled and roasted groundnut seeds (the two traditional methods of processing groundnut seeds). The Ca value (13.75-21.41mg/100g)compared closely with the values 10.2-23.1mg/100g reported for cashew nut [19,21]. Relative to the recommended daily allowance (RDA) of calcium (1000mg) for adult [22], 1kg of the sample can supply up to 21.41% of daily requirement of Ca. Calcium forms component of bones and is necessary for blood clotting and most enzyme–mediated processes [19,23]. One of the factors that influence the availability of Ca for absorption is the presence of substances which form insoluble complexes with Ca such as antinutritional factors [23] and phosphate ions. Phosphorus-rich diets with low Ca levels have been associated with increased loss of Ca in the bone [24]. Any diet with the Ca/P ratio above one is considered “good” [25]. With the high ratio observed in the present study the sample may be considered biologically rich as it would encourage absorption of Ca in the gastrointestinal tract. Ca (in associate with P) is required for blood formation and; bone, teeth and muscle growth and maintenance [21,26,27].

The observed reduction in K, Mg and Fe concentrations (Table 1) were also reported byMusa and Ogbadoyi [28] and Audu and Aremu [25] for *Hibiscus sabdariffa* leaves and red kidney bean with increasing boiling time. Adeniji and Tenkuoano [29] working with plantain-banana hybrid submitted that while the values for Mg and Fe decreased as blanching time was extended, K was not affected.

K plays a large role in supporting the nervous system and natural heart rhythm and has been shown to prevent stroke [30]. The plant food is apparently not a good source of dietary K as 1kg mass can provide about 2.41% of the 4700mg RDA of K for adult [22]. The sample on the other hand, could be adjudged good source for Mg as 1kg mass can supply as much as 21.06% of the 320-420mg RDA of Mg for adult [22]. Magnesium is an activator of many enzyme systems and helps in the maintenance of the electrical potential of nerves and cell membranes [20]. Fe was the most thermo-labile mineral in the sample and was lost completely after 45min maceration. Provided the plant food is not macerated for up to 30min, it is an excellent source of dietary Fe as 100g can supply over 94% of the 8mg RDA of Fe for

adult. Iron in the form of haemoglobin acts as carrier of oxygen from the lung to the body tissues. It is also essential for normal functioning of the central nervous system (CNS) and in the oxidation of carbohydrate, protein and fat [31].

The sample is a good source of dietary Cu as 100g quantity can provide as much as 32% of the 900mg RDA for adult [22]. Cu in association with Fe, is a component of blood haemoglobin which carries oxygen [21]. The value obtained for Mn was higher than 1.7-1.6mg/100g reported for red kidney bean [21]. Mn is a micro element involved in normal bone structure, reproduction and functioning of the CNS [32]. It also acts as activator of many enzymes [33]. Ignoring any possible effect of antinutrients, the plant food is an excellent source of dietary Mn as 100g at all levels of processing can supply as much as 100% of the 1.2-3.2mg RDA of Mn for adult [22].

C. schweinfurthii is also a good source of Zn and I as 1kg mass at all levels of processing can adequately supply the adult RDA of Zn (8-11mg), and 35-80% of that of I (150mg) [22]. The observed value for Zn was comparable to the value 810.0-880.0µg/100g reported for plantain-banana hybrid [29]. Zn, a trace element, plays a vital role in gene expression, regulation of cellular growths and functions as a co-factor of enzymes responsible for carbohydrates, proteins and nucleic acid metabolism [34]. It is also implicated in the management of diabetes [35], heart diseases and metabolism of cholesterol [36]. Iodine on the other hand is involved in the synthesis of thyroid hormones by the thyroid gland. It is also required by the developing fetus due to its effect on brain development.

One kilogramme mass of the sample macerated to eaten tenderness can supply as much as 19.47% of the RDA (1200-1300mg) of Na for adult. Na is required for maintenance of fluid balance and normal osmotic pressure in the body [28,37]. Together with potassium, Na is required for nervous transmission, the control of glucose absorption and normal retention of protein during growth [30,38]. The Na to K ratio in the body is of great concern for the prevention of high blood pressure – with the value of less than one being recommended [25]. The Na/K ratios (from this work) for CS_{raw} and CS_{45} were below one while those for CS_{15} and CS_{30} were above one. Consequently, the consumption of raw or over processed sample could contribute to reduction of high blood pressure.

The lead content of the sample at all levels of processing (12.83-21.34µg/100g) were lower than 66.0, 76.0, 55.0 and 44.0µg/100g reported for groundnut, melon, oil bean and palm kernel seeds respectively by Onyeike and Acheru [14]. The values may be site specific relating to the extent of pollution of the area where the sample was collected [39]. Lead is present (at very low levels) in all foods due to its ubiquitous presence in the environment [40]. Relative to daily permissible amount (for adult of 65kg body weight) of about 232.14µg [41] the plant food at all levels of processing is safe as far as lead poisoning is concern as 1kg mass can only supply 128.3-213.4µg of Pb.

The sample is a good source of dietary selenium especially when processed to eaten tenderness (CS_{30}) as 1kg mass can supply over 145% of the 55.0µg RDA of Se for adult [22]. The trace element has been identified as component of some enzymes (selenoenzymes) like glutathione peroxidase and thioredoxin reductase which are involved in controlling tissue concentrations of highly reactive oxygen-containing metabolites. Consequently, the element is part of the antioxidant systems that protect the body tissues against oxidative stress and is also involved in modulation of growth and development [42].

Table 1. Mineral concentrations[a] of raw and heat processed *Canarium schweinfurthi* pulp flour

Mineral	Samples			
	CS_{raw}	CS_{15}	CS_{30}	CS_{45}
Ca (mg/100g)	13.75	21.41	21.24	16.74
K (mg/100g)	11.34	10.83	10.60	7.69
Mg (mg/100g)	8.37	7.72	5.84	3.64
Na (mg/100g)	2.33	13.76	23.36	6.03
P (µg/100g)	10.67	16.0	18.67	21.33
Pb (µg/100g)	12.83	17.25	21.34	13.84
Cu (µg/100g)	221.33	287.33	218.0	209.33
Fe (mg/100g)	7.78	7.55	0.35	ND
I (µg/100g)	12.0	9.33	6.67	5.33
Mn (mg/100g)	4.61	4.76	4.33	2.32
Zn (µg/100g)	776.0	852.0	1432.0	1787.0
Se (µg/100g)	5.33	6.0	8.0	2.0

[a]*Values are means of duplicate determinations on dry matter basis. ND = not detected*

Table 2. Differences in mineral concentrations between raw and heat processed *Canarium schweinfurthii* pulp flour

Mineral	[a]Differences (percentage difference)		
	$CS_{raw} - CS_{15}$	$CS_{raw} - CS_{30}$	$CS_{raw} - CS_{45}$
Ca	-7.66(55.71)	-7.49(54.47)	-2.99(21.75)
K	0.51(4.50)	0.74(6.53)	3.65(32.19)
Mg	0.65(7.77)	2.53(30.23)	4.73(56.51)
Na	-11.43(490.56)	-21.03(902.58)	3.7(158.80)
P	-5.33(49.95)	-8.0(74.98)	-10.66(99.91)
Pb	-4.42(34.45)	-8.51(66.33)	-1.01(7.87)
Cu	-66.0(29.82)	3.33(1.5)	12.0(5.42)
Fe	0.23(2.96)	7.43(95.5)	---
I	2.67(22.25)	5.33(44.42)	6.67(55.58)
Mn	-0.15(3.25)	0.28(6.07)	2.29(49.68)
Zn	-76(9.79)	-656(84.54)	-1011(130.28)
Se	-0.67(12.57)	-2.67(50.94)	3.33(62.48)

[a]*Negative means increased. Values in parentheses denote percentage difference*

The vitamin contents of raw and macerated samples are shown in Tables 3 and 4. The change in concentration of the vitamins as a result of processing presented as percentage difference between the level of the vit in the raw and processed samples are shown in Tables 5 and 6 for fat-soluble and water-soluble vitamins respectively. Vit C (2.37-2.35mg/100g) was the most abundant vit in the sample followed by vit E (1.97-1.84mg/100g) and then vit B3 (1.48-1.27mg/100g). The vit contents of the sample were made most available at 15min maceration (Tables 3-6). The observed trend (Tables 3 and 4) was similar to that reported by Musa and Ogbadoyi [28] for β-carotene in boiled *Hibiscus sabdariffa* leaves. Vitamin A was the most sensitive fat-soluble vitamin in the sample at all levels of maceration while for water-soluble vitamins, B3 was the most sensitive at CS_{15} and, B2 at CS_{30} and CS_{45}.

Table 3. Concentrations[a] of Fat-soluble Vitamins in raw and heat processed *Canarium schweinfurthi* pulp flour

Vitamin	Samples			
	CS_{raw}	CS_{15}	CS_{30}	CS_{45}
A (µg/100g)	3.84	3.95	3.24	3.02
D1 (IU/100g)	1.49	1.52	1.47	1.29
D3 (IU/100g)	1.80	1.82	1.72	1.54
E (mg/100g)	1.92	1.97	1.89	1.84
K (µg/100g)	12.01	12.24	10.94	10.47

[a]*Values are means of duplicate determinations*

Table 4. Concentrations[a] of water-soluble vitamins in raw and heat processed *Canarium schweinfurthii* pulp flour

Vitamin	Samples			
	CS_{raw}	CS_{15}	CS_{30}	CS_{45}
Thiamine, B1,(µg/100g)	892.45	924.36	884.08	907.85
Riboflavin, B2 (µg/100g)	166.29	169.44	158.48	145.23
Niacin, B3 (mg/100g)	1.42	1.48	1.38	1.27
Pantothenate, B5(µg/100g)	506.64	512.75	494.54	483.99
Pyridixine, B6 (mg/100g)	1.20	1.23	1.16	1.06
Folate, B9 (µg/100g)	48.68	50.70	49.06	46.51
Ascobate, C (mg/100g)	2.31	2.37	2.26	2.35

[a]*Values are means of duplicate determinations*

Table 5. Difference in fat-soluble vitamins contents between raw and heat-processed *Canarium schwenfurthii* pulp flour

Vitamin	[a]Differences (percentage differences)		
	$CS_{raw} - CS_{15}$	$CS_{raw} - CS_{30}$	$CS_{raw} - CS_{45}$
A	-0.12(3.05)	0.60(15.66)	0.82(21.4)
D1	-0.03(2.22)	0.02(1.55)	0.20(13.64)
D3	-0.03(1.50)	0.07(4.12)	0.25(14.04)
E	-0.05(2.40)	0.03(1.77)	0.08(4.12)
K	-0.24(1.97)	1.07(8.88)	1.54(12.80)

[a]*Negative means increased. Values in parentheses denote percentage difference*

Table 6. [a]Differences in water-soluble vitamins contents between raw and heat processed *Canarium schweinfurthii* pulp flour

Vitamin	Difference (percentage difference)		
	$CS_{raw} - CS_{15}$	$CS_{raw} - CS_{30}$	$CS_{raw} - CS_{45}$
B1	-31.90(3.57)	8.40(0.94)	-15.40(1.773)
B2	-3.10(1.86)	7.80(4.69)	21.10(12.69)
B3	-0.06(4.23)	0.04(2.82)	0.15(10.56)
B5	-6.20(1.22)	12.10(2.39)	22.60(4.46)
B6	-0.03(2.67)	0.04(3.09)	0.14(11.34)
B9	-2.02(4.15)	-0.38(0.78)	2.17(4.46)
C	-0.06(2.43)	0.05(2.17%)	-0.05(1.9)

[a]*Negative means increased. Values in parentheses denote percentage difference*

The abundance of vit C in the sample is of nutritional importance as the vitamin is essential to humans who lack the terminal enzyme (L-gluconolactone oxidase) in its biosynthetic pathway. It is a dietary antioxidant acting as an electron donor for eight enzymes in humans [43]. The vitamin has also been found to reduce gastric cancer risk by preventing the formation of potentially mutagenic N-nitroso compounds in the stomach [44]. One kilogramme of the plant food can supply at most 31% of the 75-90mg RDA of vit C for adult. The sample is also a good source for vitamin E and K as 1kg mass can supply 100% of the 10mg and 90-120µg RDAs of vitamin E and K respectively. The vitamin E contents of the sample (1.966 -1.841mg/100g) was higher than 0.85 and 0.70mg/100g obtained for raw soybean and English walnut respectively [45,46]. Vitamin E, an antioxidant, is exclusively obtained from the diet and plays a role in modifying the development of oxidative stress-induced diseases by quenching or neutralizing excess endogenously or exogenously produced radicals [47]. Vitamin K, also an essential fat-soluble vitamin, acts as cofactor for a microsomal enzyme, y-glutamyl, or vitamin K–dependent carboxylase which catalyzes the carboxylation reaction that transforms a specific glutamate (Glu) residue of prothrombin precursor to y-carboxyglutamate (Gla) residue, forming native prothrombin that is involved in the haemostatic coagulation process [48].

The plant food is a poor source of Vitamin A and D at all levels of processing (Table 3) as 1kg mass can supply at most 5.64% and 4.56% respectively of the daily requirements of the vitamins. The result shows that the sample at all levels of processing can provide good or moderate amount of various B vitamins The values (Table 4) for thiamine, niacin, pyridoxine and folate were higher than their reported values for egg (40µg, 75µg, 0.17mg and 47µg/100g respectively) [46]. The vitamin B1, B3 and B6 values were also higher than their respective values; 341µg, 1125µg and 0.537mg/100g reported for English walnut [46].

B-vitamins principally function in making red blood cells and in macronutrient metabolism helping the body to use energy-yielding nutrients such as carbohydrates, fats and proteins for fuel [23,49]. They also help cells to multiply by making new DNA.

The B- vitamin contents of the plant food at all levels of processing were high relative to their RDA values. One kilogramme of the sample can supply 100% of the 1.1-1.3mg, 14-16mg, 5mg and 400µg adult RDAs of B2, B3, B5 and B9 vitamins respectively. One hundred gramme mass can provide over 80% and 70% of the 1.1-1.2mg and 1.5-1.7mg adult requirements for B1 and B6 respectively. Consequently, the sample could be considered good source for water soluble vitamins.

Maceration is hydrothermal processing that involves hydration and heating [9]. The observed increase in the micronutrients contents of the sample is attributable to the disruption of the cell structure and membrane partitions of the seeds by the processing heat. This enables the release of the micronutrients from entrapment in the plant matrix [11]. The increase may also be due to inactivation of antinutrients. According to Yadav and Sehgal [10] and Akinyele and Oroluntoba [50], thermal processing like maceration, blanching, boiling or cooking improves the nutrients availability of foods by destroying certain antinutritional factors such as phytate, polyphenol and oxalate. Soluble antinutrients like oxalate may also be reduced when the wet-heat treatment causes considerable skin (epidermal) rupture and facilitate their leakage into the processing water [51].

The observed reduction in the micronutrient content of the sample with increased processing time may be attributed to destruction due to heat lability and thermo-sensitivity (oxidation) of the micronutrients mostly vitamins [52,53,54]. The bulk of the micronutrient loss during wet-

heat treatment had been attributed to leaching into the processing water which is enhanced by heat that increased the solubility of some of the nutrient [53].

Consequently, the value obtained for each micronutrient at any level of maceration represented what was left of the micronutrient as a result of the interplay between factors increasing, and those decreasing its level in the plant food [49].

4. CONCLUSION

This study has shown that maceration affects the micronutrient contents of *C. schweinfurthii* pulp. Highest concentration was obtained for all the vitamins and Ca, Cu and Mn at 15min maceration. Although the plant food is consumed as snacking item (masticatory), it could be processed to meet specific micronutrients need.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Severi S, Bedogni G, Manzieri M, Polim M, Battistini N. Effect of cooking and storage methods on the micronutrient content of foods. Eu J Cancer Prev. 1997;6(1);21-24.
2. Anyalogbu EA. Human nutrition. In: Anyadoh S, Ezeji E, editors. Undergraduate biology I. 1st ed. Owerri: Readon Publishers ltd; 2010.
3. Kader A, Perkins-Veazie PM, Lester GE. Nutritional quality of fruits, nuts and vegetables and their importance in human health. USDA Hand Book. 2004;66.
4. Agbaire PO, Emoyan OO. Nutritional and antinutritional levels of some local vegetables from Delta State, Nigeria. Afr J Food Sci. 2012;6(1);8–11.
5. Meregini AOA. Some endangered plants producing edible fruits and seeds in Southeast Nigeria. Fruits. 2005;60(3):211-20.
6. Agu HO, Ukonze JA, Uchola NO. Quality characteristics of crude and refined atili oil. Pak J Nutr. 2008;7(1);27-30.
7. FAO. Effect of food processing on dietary carbohydrate: Carbohydrate in human nutrition. Report of a joint FAO/WHO Expert consultation. FAO Food and Nutrition paper-66; Rome; 1998.
8. Audrey M, Audia B, Olive-Jean B. Effect of processing on nutrient content of foods. Cajaritic les. 2004;37(3):160-64.
9. Sefa-Dedeh S, Stanley DW, Voisey PW. Effect of soaking time and cooking conditions on texture and microstructure of cowpeas (*Vigea unguiculata*). J Food Sci. 1978;43:1832-38.
10. Yadav SK, Sehgal S. Effect of domestic processing and cooking methods on total, HCl extractable iron and *In vitro* availability of iron in spinach and amaranth. Nutr Health. 2002;16:113-20.
11. Hotz C, Gibson RS. Traditional food processing and preparation practices to enhance the bioavailability of micronutrients in plant-based diets. J Nutr. 2007;137(4):1097-100.
12. Lewu MN, Adebola PO, Afolayan AJ. Effect of cooking on the mineral and antinutrient contents of the leaves of seven accessions of *Colocasia esculenta* (L.) Schott growing in South Africa. J Food Agric Environ. 2009;7(3&4):359-69.

13. AOAC (Association of Official Analytical Chemists). Official Methods of Analysis, 17th Edition. Gaitherburg, M.D; 2000.
14. Onyeike EN, Acheru GN. Chemical composition of selected Nigerian oil seeds and physicochemical properties of the oil extracts. Food Chem. 2002;77:431-37.
15. AOAC (Association of Official Analytical Chemists), Codex – Adopted – AOAC Method. AOAC International. 2006;50(1):1-2.
16. Santos J, Mendiola JA, Oliveira MBPPB, Ibáñez E, Herrero M. Development of a HPLC-DAD- MS/MS method for simultaneous determination of fat- and water- soluble vitamins in green leafy vegetables. J of Chromatography A. 2012;1261:179–188.
17. Canellas J, Saura-Calixto F. Mineral composition of almond varieties (*Prunus amygdalus).* Zeitschriftfr food investigation Undforschung. 1982;174:129-31.
18. Aremu MO, Olonisakin A, Otene JW, Atolaye BO. Mineral content of some agricultural products grown in the Middle Belt of Nigeria. Oriental J Chem. 2005;21;419-26.
19. Aremu MO, Olonisakin A, Bako DA, Madu PC. Compositional studies and physicochemical characteristics of cashew nut (*Anarcadium occidentale*) flour. Pak J Nutr. 2006;5(4):328-33.
20. Eke-Ejiofor J, Kiin-Kabari DB, Chukwu EC. Effect of processing method on the proximate, mineral and fungi properties of groundnut (*Arachis hypogea*) seed. J Agric Biol Sci. 2012;3(1):255-61.
21. Ologunde MO, Omosebi MO, Ariyo O, Olunlade BA, Abolaji RA. Preliminary nutritional evaluation of cashew nut from different locations in Nigeria. Conti J Food Sci and Technol. 2011;5(2):32-36.
22. DRI, (Dietary Reference intakes). Recommended intakes for individuals. Food and Nutrition Board, Institute of Medicine, National Academics; 2004.
23. Vunchi MA, Umar AN, King MA, Liman AA, Jeremiah G, Aigbe CO. Proximate, Vitamins and mineral Composition of Vitexdoniana (Black plum) Fruit pulp. Nig J Basic and Appl Sci. 2011;19(1):97-101.
24. Onyeike EN, Ayalogu EO, Okaraonye CC. Nutritive value of the larvae of raphia palm beetles *(Oryctes rhinoceros)* and weevil (*Rhyncophorus pheonicis).* J Science of Food and Agriculture. 2005;85:1822-28.
25. Audu SS, Aremu MO. Effect of processing on chemical composition of red kidney bean (*Phaseolus vulgaris* L) flour. Pak J Nutr. 2011;10(11):1069-75.
26. Ogunlade I, Olaofe O, Fadare I. Chemical composition, amino acids and nutritional properties of selected seafoods. J Food Agric and Environ. 2005;3:130-33.
27. Umar KJ, Hassan LG, Ado Y. Mineral Composition of *Detarium microcarpum* grown in Kwatarkwashi, Zamfara State, Nigeria. Int J Pure and Appl Sci. 2007;1(2):43-48.
28. Musa A, Ogbadoyi EO. Effect of processing methods on some micronutrients, antinutrients and toxic substances in *Hisbiscus sabdariffa*. Asian J Biochem. 2012;7:63-79.
29. Adeniji TA, Tenkuoano A. Effect of processing on the proximate, mineral and pasting properties of whole flour made from some new plantain and banana hybrids pulp and peel mixture. Agro Sci J Trop Agric Food, Environ. 2008;7(2):99-105.
30. Jannifer K. The Vital Importance of Mineral for Our Health; 2009. Accessed 17 November 2013.
    Available: http:// www.selfgrowth.com/articles.html.

31. Adeyeye EI, Otoketi MKO. Proximate composition and some nutritionally valuable minerals of two varieties of *Capsicum annum* (Bell and Cherry Peppers). Discov and Innov. 1999;11(1&2):75-81.
32. Norman A, Joseph N. Food Science, 3rd ed. CBC processing; 1995.
33. McDonald P, Edward RA, Greenhalti FD, Morgan CA. Animal Nutrition. Prentices Hall, London; 1995.
34. Camera F, Amaro CA. Nutritional aspect of zinc availability. Int J Food Sci and Nutr. 2003;47:143-51.
35. Okaka JC, Okaka ANO. Food composition, spoilage and shelf life extension. Ocjarco Academic Publishers, Enugu, Nigeria; 2000.
36. Oderinde RA, Ajayi IA, Adewuyi A. Evaluation of the mineral nutrients, characterization and some possible uses of *Blighia unijugata* Bak seed and seed oil. Elec J Environ Agric and Food Chem. 2009;8(2):120-29.
37. Aliyu HM, Morufu AI. Proximate analysis of some leafy vegetables (Roselle, jute and bitter leaf). Int J Food and Agric Res. 2006;3:19-198.
38. Adeyeye EI. Determination of the chemical composition of the nutritionally valuable parts male and female common West African fresh water crab (*Sudnanautes africanus).* Int J Food Sci and Nutr. 2002;53:189-96.
39. Agunbiade FO, Fawale AT. Use of Siam weed biomarker in assessing heavy metal contaminations in traffic and solid waste polluted areas. Int J Environ Sci Technol. 2008;6(2):267-76.
40. Health Canada. Chemical Contaminants; 2011: Accessed July 30 2013;
    Available: http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/index-eng.php.
41. Edebi NV, Gideon OA. Evaluation of pharmacognostical parameters and heavy metals in some locally manufactured herbal drugs. J Chem Phar Res. 2011;3(2):88-97.
42. Baum MK, Shor-Posner G. Micronutrient status in relationship to mortality in HIV-1 disease. Nutr Rev. 1998;56:135-39.
43. Englard S, Seifter S. The biochemical functions of ascorbic acid. Ann Rev Nutr. 1986;6:365-406.
44. Byers T, Guerrero N. Epidemiologic evidence for vitamin C and vitamin E in cancer prevention. Am J Cli Nutr. 1995;62:1385-92.
45. USDA. Nut, Walnuts, English. Nutrient Data Laboratary; 2005. Accessed August 2 2013.
    Available: http//www.nal.usda.gov/fnic/foodcomp/cgi-bin/list-nutedit.pl.
46. USDA. Nutrient Database; 2011. Accessed June 30 2013.
    Available: http://ndb.nal.usda.gov/ndb/search/list.
47. Diplock AT. Antioxidants and disease prevention. Molr Asp of Med. 1994;15:293-376.
48. Furie B, Furie BC. Molecular basis of vitamin K-dependent g-carboxylation. Blood. 1990;75:1753-62.
49. Gernah DI, Sengev AI. Effect of processing on some chemical properties of the leaves of the drumstick tree (*Moringa oleifera*). Nig Food J. 2011;29(1):70-77.
50. Akinyele BJ, Oloruntoba OS. Comparative studies on *Citrullus vulgaris, Citrullus colocynthis and Cucumeropsis mannii* for 'Ogiri' production. Br Microbiol Res J. 2013;3(1):1-18.
51. Albihn PBE, Savage GP. The effect of cooking on the location and concentration of oxalate in three cultivars of New Zealand grown oca (*Oxalis tuberosa*Mol). J Sci Food and Agric. 2001;81:1027-33.

52. Ejoh AR, Tanya AN, Djuikwo NA, Mbofung CM. Effect of processing and preservation methods on vitamin C and total carotenoid levels of some *Vernonia* (bitter leaf) species. J Food Agric Nutr Dev. 2005;5:105-17.
53. Rickman JC, Bruhn CM, Barrett DM. Nutritional comparison of fresh, frozen, and canned fruits and vegetables II. Vitamin A and carotenoids, vitamin E, minerals and fiber. J Sci Food Agric. 2007;87:1185-96.
54. Gernah DI, Ega BM, Umoh UE. Effect of boiling time on the quality of Zogale: A snack food produced from peanut (*Arachis hypogea*) cake and boiled *Moringa oleifera* leaves. Afri J Food Sci. 2012;6(10):287-93.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=571&id=31&aid=5064