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Potentials of raw and cooked walnuts (*Tetracapidium conophorum*) as sources of valuable nutrients for good health

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Abstract

Background: The present study estimated nutrient composition of walnuts before and after cooking with respect to its potential as valuable source of nutrients for daily intake.

Method: Walnut fruits were purchased from five different markets in Ijebu-Ode local government area and its environs. The fruits samples were divided into two portions, labelled R (for raw) and C (cooked). The C samples were cooked at 100°C for 1 hr and allowed to cool to room temperature. The seeds of both C and R samples were ground and analyzed for proximate, macro and micro minerals using methods of Association of Official Chemists.

Results: The results obtained showed that both raw and cooked walnuts are rich in fat, iron (Fe), manganese (Mn), and copper (Cu) in amounts that are within daily recommended intake per 100 g of walnut seeds. They also contained appreciable levels of protein, phosphorus (P), calcium (Ca), and magnesium (Mg) but with low content of moisture (MC), carbohydrate, fiber, sodium (Na) and potassium (K). Boiling significantly affected the levels of protein, carbohydrate, ash, moisture content, fat, nitrogen, calcium, sodium, copper, zinc, phosphorus, potassium, manganese and iron

Conclusion. The study reveals that walnut is nutritious due to its appreciable level of protein and presence of various essential and macro minerals. Its low content of sodium and potassium is beneficiary in hypertensive condition as snack. The study suggests future bio-fortification of walnut with zinc, which may bring about a co-increase in Ca and protein content.

Keywords: *Nutrient composition; raw and cooked walnuts, Tetracapidium conophorum.*

Résumé

Contexte: La présente étude a estimée la composition nutritive de noix avant et après la cuisson par rapport à son potentiel en tant que source précieuse de nutriments pour l'apport journalier.

Méthode: Les fruits de noix ont été achetés dans cinq différents marchés de la zone de gouvernement local d'Ijebu-Ode et ses environs. Les échantillons de fruits ont été divisés en deux parties, R marqué (pour les crus) et C (cuits). Les échantillons du groupe C ont été cuits à 100 ° C pendant 1 h et ont été laissées refroidir à la température ambiante. Les graines des deux groupes d'échantillons C et R ont été broyés et analysés pour les minéraux proches, macro et micro en utilisant des méthodes de l'Association des chimistes officiels.

Résultats: Les résultats obtenus ont montré que les noix à la fois crus et cuits sont riches en matières grasses, le fer (Fe), le manganèse (Mn) et le cuivre (Cu) dans des quantités qui sont dans l'apport journalier recommandé par 100 g de graines de noix. Ils contenaient également des taux appréciables de protéines, de phosphore (P), de calcium (Ca) et de magnésium (Mg), mais avec une faible teneur en humidité (MC), de s glucides, de fibres, de sodium (Na) et de potassium (K). Le point d'ébullition a significativement affecté les niveaux de protéines, de glucides, de cendres, de teneur en humidité, de graisse, d'azote, de calcium, de sodium, de cuivre, de zinc, de phosphore, de potassium, de manganèse et de fer

Conclusion: L'étude révèle que la noix est nutritive en raison de son niveau appréciable de protéines et la présence de minéraux essentiels et macro. Sa faible teneur en sodium et potassium est bénéficiaire dans un état hypertensif comme goûter. L'étude suggère future bio-fortification de la noix avec le zinc, ce qui peut entraîner une augmentation simultanée en Ca et en teneur de protéines.

Mots-clés: *Composition des éléments nutritifs: noix crues et cuites, Tetracapidium conophorum.*

Introduction

Walnut is a general English name for small flowering plants that bear nuts, they are popular for their nuts and timber, which are valuable agricultural produce. Walnut comprises of different family of nuts with peculiar characteristics that are region specific. The three documented families of walnut are, namely, Juglandaceae (species *Jungla regia* is mostly cultivated in Europe and New world and its common name in English is walnut); Euphorbiaceae (species *Tetracarpidium conophorum*, commonly known as African walnut is cultivated in Nigeria, Cameroon

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and Ghana); and the Olacaceae family (species *Coula edulis*, also known as African walnut, is mostly grown in Congo, Gabon and Liberia) [1].

African walnut, *Tetracarpidium conophorum*, grown in Nigeria, belongs to the family Euphorbiaceas. It is a woody perennial climber found in the forest regions of Africa and India and its alternative scientific name is *Pluckennetia conophora* Mull. (Arg) [2, 3, 4]. As described by Willis [5] but with modifications, African walnut bears fruits in capsules which are greenish in colour when immature and greenish yellow when fully ripe. The capsules contain four sub-globular seeds in enclosed hard dark brown or black shells, commonly refer to as kernels. The kernel consists of two bumpy lobes which are off-white in color and covered by a thin cream coloured skin.

In Nigeria, African walnut is an economic important forest plant that is cultivated for the production of its valuable nuts. It is a seasonal fruit grown by peasant farmers who inherited walnut farms from their grandparents. Walnut became a food plant from time immemorial and is traditionally eaten after boiling the nut, as snacks, in most part of Nigeria [6, 7, 8]. Nigerian local names for walnut include "awusa" or "asala" (Yoruba), "ukpa" (Igbo), "okhue" or "okwe" (Benin), "ekporo" (Efik and Ibibio). It is popular across major towns in southern Nigeria such as Akamkpa, Akpabuyo, Abak, Etinan, Ibadan, Ijebu-Ode, Kogi, Lagos, Ogbomoso, Oyo, and Uyo [9, 10]. is known as "kaso" or "ngak" in western Cameroon and serves as an edible nut between meals [11].

Numerous health benefits of walnut have been reported apart from its use as food. There are reports on its folk-lore use as medicine, which include treatment of prolonged and constant hiccups [12], reduction of diabetic complications [13], anticancer property [14], and male-fertility agent [15]. It is also used as herb to detoxify kidneys, strengthen the back and knees, moisten the intestines, cure constipation and asthma that are not acute [9]. Phytochemical analysis of African walnut indicates that it contains useful organic compounds such as omega-3 fatty acids and phytosterols that may reduce the risk of cardiovascular diseases and level of cholesterol [16, 17]. It also contains phytates, flavones, and phytoestrogens that improve prostate cancer and menopausal symptoms [18, 19]. Ajaiyeoba and Fadare [15] reported the anti-microbial activities of walnut and it was also reported to possess hypolipidemic effects when eaten [20], suggestive of the presence of alkaloids [9].

A good number of research studies have been carried out on African walnut, most especially on its chemical components. Ganiyu and Mofoluso [21] determined the proximate, minerals, antinutrient composition and zinc bioavailability among some Nigerian wild seeds including African walnut. Edem *et al.* [4] estimated the proximate composition and heavy metal content of African walnuts obtained in Calabar and Ayoola *et al.*, [9] evaluated its phytochemical composition to ascertain its uses as medicine. However, these studies did not include walnuts collected in Ijebu-Ode and its environments in southwestern Nigeria, where walnuts are abundant and have been domesticated for decades. More importantly, a detailed nutritive analysis and effect of cooking that could boost knowledge on the potential of both raw and cooked walnuts to contribute to the daily nutrient requirement and improved health is required. Furthermore, many of the studies were carried out on raw walnuts rather than on the cooked form that it is consumed by Nigerian populace. The purpose of the present study was to estimate nutrients in walnut seeds, evaluate the effect of boiling on these nutrients and its contribution to nutrient requirements.

Materials and methods

Sample collection and preparation

Raw walnut samples were purchased, randomly, from five popular local markets within four local government areas (LGAs), around Ijebu-Ode LGA and its environs in Ogun state, namely, Oke-Aje (Ijebu-Ode LGA), Imushin market (Ijebu-East LGA), J4 market (Ijebu-East LGA) Mamu market (Ijebu-North LGA) and Ejinrin (Epe LGA). The walnut samples were kept in polythene sample bags and transported to Chemistry laboratory, Tai Solarin University of Education and Central Laboratory, University of Ibadan, Ibadan for laboratory analyses. Thirty wholesome walnut fruit samples were handpicked from the lots purchased at the five different markets. The selected samples were washed with deionized water, divided into two parts and labelled as raw (R) and cooked (C). The nuts from the C samples were boiled at 100°C until palatable (for about 1h) and allowed to cool to room temperature. The seeds of both the C and R samples were then removed, cleaned with deionized water again and wiped with new cleaned tissue paper and thereafter, chopped into smaller pieces using a knife with steel blade. The C and R samples were divided into sub-portions for proximate, macro-mineral and micro-mineral analyses. Each sub-portion of R and C samples in four replicates was dried in a hot-air oven at 65°C for 5 min and ground using a laboratory

attrition mill. The powdered samples were sieved into 4mm particle sizes and stored in screw capped bottles at 4°C for further analyses.

Assay methods

Analyses were carried out on the prepared four replicate samples using modified standard methods of AOAC [22]. Dry matter was determined by oven drying 3.0 g of 4mm particle size sample at 65°C until a constant weight is assumed (Thermostat oven, DNP-9022-1A, Everichmed, China) and its value was taken as the proportion of the final weight in percent while the moisture content was taken as proportion of weight loss also in percent. Ash content was by combustion of 1.0 g of 4mm particle sizes at 500°C for 4h in a muffle furnace (SXL-1208, Gallenkomp, England) and left to cool overnight to room temperature, the ash content was measured as the residual weight proportion in percent and kept at 4°C for elemental analysis.

Macronutrient analysis

Crude protein content was determined in digested samples based on micro Kjeldahl method (% total N x 6.25, KDN-102C, Shanghai QianJian, China). The crude fat was extracted in petroleum ether using Soxhlet extractor at 40 - 60°C. Crude fibre was obtained by step-wise digestion of 1.0 g fat-free dry matter in H_2SO_4 and NaOH, the generated residue was oven dried overnight at 120°C and cooled at 60°C for 2hr in muffle furnace and its proportion is measured in percent. The total carbohydrate of the flour samples were calculated by difference.

Mineral analysis

The elemental compositions were also determined according to the methods described by AOAC [22]. A gram ash of each sample was digested, subsequently, in a mixture of 2.5 ml selenium/H_2SO_4 (3.5g Se/1L H_2SO_4) at 220°C and later in 3ml of hydrogen peroxide (H_2O_2) at 350°C. The residue obtained was re-suspended in selenium/H_2SO_4 mixture and analyzed for phosphorus (P), sodium (Na), magnesium (Mg), manganese (Mn), potassium (K), calcium (Ca), iron (Fe), zinc (Zn) and copper (Cu). Phosphorus was determined using colorimetric method; calcium, potassium and sodium were determined using Jenway Digital Flame Photometer (PFP7 model) and other minerals were determined using Buck Scientific Atomic Absorption Spectrophotometer (BUCK 210VGP model).

Statistical analysis

The collected data on the nutrients composition of both raw and cooked walnuts were subjected to descriptive statistics for precision measures. Analysis of Variance (ANOVA) for detection of significant difference in the nutrient contents between the raw and processed (boiled) walnuts and among replicate samples was also carried out. Pearson correlation analysis was used to evaluate any useful pair-wise relationships among the nutrients for possible bio-fortification objectives in walnuts. Statistical Analysis System software package (SAS, 2002) was used to carry out the analyses.

Results

Levels of macronutrients and minerals in raw and cooked walnuts

The descriptive statistics of proximate composition of both raw and boiled walnuts are as shown in table 1 and figures 1a to 1d show the trend of nutrient' level between the raw and cooked walnuts. The figures indicated that among the proximate, the levels of MC, ash and COH were higher in the raw nuts than in the cooked nuts while levels of protein and fat were higher in the cooked nuts. Among the macro-minerals, raw walnuts were slightly higher in phosphorus (P), magnesium (Mg) and potassium (K) contents, but with lesser levels of nitrogen (N), sodium (Na) and calcium (Ca) than the cooked walnuts. It was also observed that among the micro-minerals, raw walnut seeds had higher levels of manganese (Mn) and iron (Fe) than boiled walnuts while levels of copper (Cu) and zinc (Zn) were higher for boiled walnuts. In a summary, cooking increased the levels of protein, fat, nitrogen, sodium, calcium, copper and zinc but reduced the levels of ash, carbohydrate, moisture content, iron, magnesium, manganese, phosphorus and potassium.

Variation and effect of boiling on nutrient levels of walnut seeds

The results obtained revealed that the levels of protein, fat, nitrogen, calcium, sodium, copper, and zinc in raw walnut increased with boiling by 28.9%, 10.4%, 41.5%, 7.4%, 30.2%, 14.7% and 5%, respectively, while carbohydrate, ash, moisture content, phosphorus, potassium, manganese and iron decreased with boiling by a proportion of 33.9%, 20.1%, 75.7%, 8.2%, 1.8%, 11.7%, and 59.8%, respectively. However, the mean level of magnesium in both raw and boiled walnut remained the same. A very large variation was observed across all the assessed walnuts for protein, fat, carbohydrate, moisture content, Na, Fe ($P<0.0005$) and Mn

Table 1: Descriptive statistics for nutrient composition of Raw and Boiled Walnuts

Category	Nutrients	Mean	SD	SE (±)	CV	Range	Min.	Max.
	Raw walnut							
Proximate composition (g/100g)	MC	0.74	0.09	0.04	11.93	0.18	0.65	0.83
	Protein	15.09	0.36	0.18	2.42	0.79	14.6	15.39
	Fat	45.66	0.87	0.44	1.91	1.79	44.88	46.67
	COH	34.53	0.92	0.46	2.66	1.7	33.72	35.42
	Ash	5.37	0.43	0.22	8.09	0.95	5.06	6.01
Macro-minerals (g/100g)	Ca	0.47	0.02	0.01	3.47	0.04	0.45	0.49
	Mg	0.27	0.01	0.01	4.87	0.03	0.25	0.28
	P	0.37	0.05	0.03	14.63	0.12	0.3	0.42
	N	2.26	0.48	0.24	21.27	1.03	1.82	2.85
	K	1.05	0.02	0.01	2.03	0.05	1.03	1.08
	Na*	0.054	11.56	5.78	2.15	20.92	527.09	548.01
	Mn	43.57	1.28	0.64	2.94	2.98	42.08	45.06
Micro-minerals (mg/Kg)	Fe	362.1	3.63	1.81	1	7.85	358.17	366.02
	Cu	10.71	0.48	0.24	4.48	0.99	10	10.99
	Zn	16.51	0.38	0.19	2.3	0.8	16.04	16.84
	Boiled walnuts							
	MC	0.18	0.05	0.03	30.43	0.12	0.12	0.24
Proximate composition (g/100g)	Protein	19.45	0.75	0.37	3.83	1.34	18.78	20.12
	Fat	50.42	0.67	0.34	1.33	1.33	49.78	51.11
	COH	22.83	0.15	0.08	0.68	0.34	22.67	23.01
	Ash	4.29	0.27	0.14	6.33	0.66	3.99	4.65
	P	0.34	0.03	0.01	8.85	0.07	0.31	0.38
Macro-minerals (g/100g)	N	3.2	0.41	0.2	12.7	0.93	2.83	3.76
	Ca	0.51	0.02	0.01	4.12	0.05	0.48	0.53
	Mg	0.27	0.02	0.01	7.86	0.05	0.24	0.29
	K	1.03	0.01	0.01	1.39	0.04	1.02	1.05
	Na*	700.08	11.62	5.81	1.66	22.31	688.92	711.23
Micro mineral (mg/Kg)	Mn	38.47	1.23	0.62	3.21	2.89	37.02	39.91
	Fe	145.74	4.35	2.18	2.99	10.57	140.45	151.02
	Cu	12.29	0.59	0.3	4.81	1.21	11.68	12.89
	Zinc	17.33	0.5	0.25	2.89	1.14	16.85	17.99
	Overall Samples							
	MC	0.46	0.31	0.11	66.73	0.71	0.12	0.83
Proximate composition (g/100g)	Protein	17.27	2.4	0.85	13.87	5.52	14.6	20.12
	Fat	48.04	2.65	0.94	5.51	6.23	44.88	51.11
	COH	28.68	6.28	2.22	21.92	12.75	22.67	35.42
	Ash	4.83	0.67	0.24	13.82	2.02	3.99	6.01
	P	0.35	0.04	0.02	12.3	0.12	0.3	0.42
Macro-minerals (g/100g)	N	2.73	0.65	0.23	23.77	1.94	1.82	3.76
	Ca	0.49	0.03	0.01	5.23	0.08	0.45	0.53
	Mg	0.27	0.02	0.01	6.05	0.05	0.24	0.29
	K	1.04	0.02	0.01	1.87	0.07	1.02	1.08
	Na*	618.81	87.53	30.95	14.15	184.14	527.09	711.23
Micro-minerals mg/Kg)	Mn	41.02	2.97	1.05	7.23	8.04	37.02	45.06
	Fe	253.92	115.71	40.91	45.57	225.57	140.45	366.02
	Cu	11.5	0.98	0.35	8.5	2.89	10	12.89
	Zinc	16.92	0.6	0.21	3.57	1.95	16.04	17.99

MC, moisture content; COH, carbohydrate.
**Sodium values are exponental of 10^{-1}*

(P>0.005) and a slight variation for N (P>0.05) but there was no significant variation for ash, P, Ca, Mg, K, Cu, and Zn.

The variation observed for the varied nutrients was contributed by the strong interaction of the state of walnut (either as raw or boiled) and

Table 2: Analysis of variance descriptive statistics for effect of replicate, boiling and their interaction on walnut

Nutrients	Mean	Model			Replicates	Processing (Raw*boiling)			replicate*Processing		
		CV	Sum of Square (SS)	R^2	Pr>F	Pr>F	%SS	Pr>F	SS	Pr>F	SS
Proximate composition g/100g											
Protein	17.26	0.858	40.08	0.997	***	**	1.71	***	38.11	*	0.27
Fat	48.04	0.46	48.59	0.996	***	ns	0.049	***	45.36	**	3.93
COH	28.68	0.299	276.47	0.999	***	***	1.68	***	273.89	***	0.89
MC	0.46	4.61	0.657	0.997	***	ns	0.002	***	0.62	**	0.029
Ash	4.83	7.81	2.55	0.82	ns	ns	87.1	*	2.33	ns	0.21
Macro-mineral g/100g											
Na*	618.8	2.285	52834.93	0.985	***	ns	0.966	***	52828.75	***	5.21
N	2.728	9.144	2.696	0.915	*	*	0.91	*	1.75	ns	0.02
Ca	0.49	3.69	0.003	0.714	ns	ns	0.0008	ns	0.002	ns	0.00
Mg	0.265	5.34	0.001	0.56	ns	ns	0.0002	ns	0.0	ns	0.0
K	1.04	1.32	0.002	0.71	ns	ns	0.001	ns	0.001	ns	0.000
P	0.35	14.11	0.003	0.24	ns	ns	0.002	ns	0.002	ns	0.001
Micro- minerals (mg/Kg)											
Fe	253.91	1.67	93647.45	0.99	***	ns	3.69	***	93623.01	ns	20.60
Cu	11.50	5.32	5.19	0.77	ns	ns	0.02	*	4.98	ns	0.209
Mn	41.02	1.72	59.61	0.96	**	ns	7.48	***	52.12	ns	0.004
Zn	16.92	2.278	1.956	0.767	ns	ns	0.396	*	1.361	ns	0.198

Duncan Grouping† between Raw (R) and cooked (C) walnuts

	Protein	Ash	Fat	COH	MC	P	N	Ca	Mg	K	Na	Mn	Fe	Cu	Zn
R	B	A	B	A	A	A	B	A	A	A	B	A	A	B	B
C	A	B	A	B	B	A	A	A	A	A	A	B	B	BA	A
%	28.9	-20	10.4	-33.9	-76	-8.2	41.5	7.4	0	-1.8	30.2	-12	-60	14.7	4.99

MC, Moisture content; COH, carbohydrate; CV, coefficient of variation; R^2, coefficient of acceptability; Pr>F, probability greater than F value.

, Significant at the 0.05 probability level; **, significant at the 0.005 probability level, *, significant at 0.0005 probability level; ns, non-significant at the 0.05 probability level*

† Duncan grouping assigned letters to show significant difference between raw and cooked walnuts. However, when both has the same letter, then they are not significantly different in their mean levels % ,increased /decreased in percentage

**Sodium values are exponential of 10^{-1}*

slightly by individual replicate of walnuts (Table 2). Strong effect of boiling was further manifested in the levels of ash, Cu and Zn that were observed not to be significant across samples but showed significant variation in their levels between raw and boiled walnuts. In contrast, levels of P, Ca and K, though, were affected by boiling but were not significantly different to levels obtained in the raw walnuts. Therefore, boiling had significant effect on the levels of protein, crude carbohydrate, moisture content, fat, Na, Fe, Mn ($P<0.0005$), ash, N, Cu and Zn ($P<0.05$) but had no significant effect on P, Ca, Mg, and K. Duncan multiple range test grouping provided a clear-cut representation of variation of the nutrients between the raw and boiled walnuts, based on the separation of their means, by assigning them into groups using letters A and B, where means with the same letters are not significantly different (table 2).

Relationship among nutrients of raw and cooked walnuts

Pearson correlation analysis was used to estimate the significant relationship among nutrients between raw and boiled walnuts for possible bio-fortification and breeding objectives. The result revealed that boiling of whole walnut fruits was significant with protein, N, fat, Ca, Na, Cu and Zn but inversely related with ash, carbohydrate, moisture content, Mn, and Fe but was insignificant with P, Mg and K (Table 3). The result means that the levels of protein, N, fat, Ca, Na, Cu, and Zn increase with boiling while that of ash, carbohydrate, moisture content, Fe and Mn decrease. Therefore, the Pearson correlation signified that boiling had positive effect on levels of crude

Table 3: Relationships between raw and boiling for nutrients based on Pearson correlation analysis method

	Protein	Ash	P	N	Fat	COH	MC	Ca	Mg	K	Sodium	Mn	Iron	Cu	Zinc
Processed	0.98***	-0.86**	ns	0.77*	0.96***	-0.99**	-0.98***	0.73*	ns	ns	0.99***	-0.92***	-0.99***	0.86*	0.73*
Protein	1	-0.80*	ns	0.87*	0.95***	-0.98***	-0.95***	0.82*	ns	ns	0.97***	-0.82*	-0.97***	0.85*	0.83**
Ash		1	ns	ns	-0.74*	0.88**	0.79*	ns	ns	ns	-0.83*	0.83*	0.87**	-0.76*	ns
P			1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N				1	0.71*	-0.82*	ns	0.94***	ns	ns	0.79*	ns	-0.76*	ns	0.87**
Fat					1	-0.94***	-0.99***	0.72*	ns	ns	0.96***	-0.89**	-0.96***	0.79*	0.79*
COH						1	0.95***	-0.76*	ns	ns	-0.99***	0.89***	0.99***	-0.86**	-0.74*
MC							1	ns	ns	ns	-0.96***	0.93**	0.97***	-0.79*	-0.73*
Ca								1	ns	ns	0.79*	ns	-0.71*	0.72*	0.92***
Mg									1	ns	ns	ns	Ns	ns	ns
K										1	ns	ns	Ns	ns	ns
Sodium											1	-0.89***	-0.99***	0.88**	0.78*
Mn												1	0.93**	-0.74*	ns
Iron													1	-0.86*	-0.71*
Cu														1	ns

MC, Moisture content; COH, carbohydrate; Ca, calcium; Cu, copper; K, potassium; Mg, magnesium, Mn, manganese; N, nitrogen; P, phosphorus

, Significant at the 0.05 probability level; **, significant at the 0.005 probability level; *, significant at 0.0005 probability level; ns, non-significant at the 0.05 probability level.*

protein, N, fat, Ca, Na, Cu, and Zn and negative effect on levels of carbohydrate, moisture content, Mn, and Fe but with no effect on levels of P, Mg and K. The result of correlation analysis supports the aforementioned results and the preceding results obtained in ANOVA. Table 3 also reveals relationships between pair of nutrients, the result showed that protein was positively correlated with N, fat, Ca, Na, Cu, and Zn but negatively correlated with ash, carbohydrate, moisture content, Mn, and Fe. Therefore, as level of protein increases in walnut seeds the level of N, fat, Ca, Na, Cu and Zn also increases but level of ash, COH, MC, Mn and Fe decreases and vice versa. Phosphorus and magnesium were observed not to be significant with any of the other assessed nutrients.

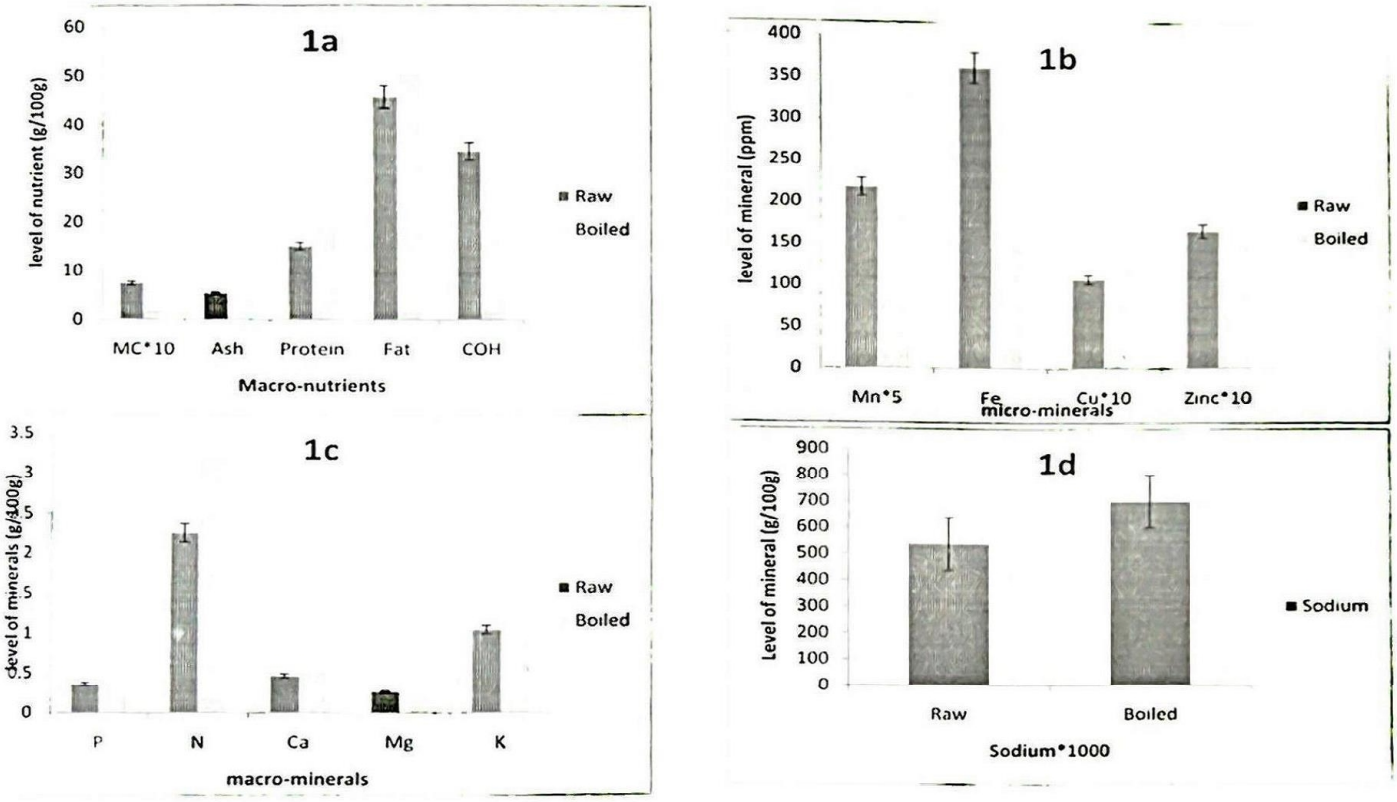

Fig. 1a –d: Level of nutrients in raw and boiled walnuts

*5 = level * factor of 5 and *10 = level * factor of 10, *1000 = level *factor of 1000

Discussion

There are earlier reports on the nutrient composition of walnut from diverse states/cities in Nigeria. Edem *et al.* [4] reported the proximate and some minerals values for raw walnuts collected in Calabar, Cross river state. Also, Ayoola *et al.* [9] reported on raw walnut in Ajaawa area of Oyo State and more recently, Udedi *et al.* [10] for only proximate composition in both raw and cooked walnuts from Akwa, Anambra state. The present study evaluated major and minor nutrients that are required by Nigerian populace in both raw and cooked walnuts from Ijebu-Ode LGA and some other close by LGAs in Ogun state and also evaluated the effect of boiling on the walnut nutrient content as additional knowledge to nutritive value of walnuts. The estimated abundance of the minerals obtained in walnuts assessed in the present study was in the following decreasing order: N > K > Ca > P > Mg > Na > Fe > Zn < Mn > Cu, which perhaps may represent their order of bioavailability in nature.

Based on close observations, levels of protein and MC obtained in the present study for walnuts from Ijebu-Ode LGA and its environs are lower than those reported for Akwa, Calabar, and Oyo with an extreme high value of MC for Oyo, while ash and COH are within range but also with extremely high value for Calabar. A very high fat content of up to half of total energy proportion was obtained for Ijebu-Ode LGA and Akwa when compared to very low fat content reported for Oyo and Calabar. Fibre content was reported only for Anambra and Ijebu-Ode but

the obtained values were low, which might be indicative of walnut as a poor source of fiber. The mineral levels obtained in the present study are higher than those of earlier reports except for level of Mg. Therefore, the walnuts from Ijebu-Ode and its environs are richer in minerals than those of Oyo, and Calabar. The presently observed disparities in the reported values of nutrient composition in raw walnuts across Nigeria might be as a result of differences in the geographical zone, soil types, analysis techniques/equipment and walnut varieties resulting into influence of genotype by environment interaction. Based on literature, the range of protein content reported in African walnuts across different parts of Nigeria is within the range of 3.21 and 43.5% for protein rich fruits and nuts [24], which indicates walnut as a good source of protein for having 12% of its energy as protein [25]. Generally, based on the present and previous reports, walnuts have low levels of fiber, ash, and moisture content as obtained in other nuts but with higher levels of macro-minerals and micro-minerals [26]. The low water content reported in walnuts is beneficial to the nut by providing it with good shelf life. Walnut could also serve as a limiting source in restricted diets of carbohydrate, potassium and sodium.

The levels of protein, fat, nitrogen, calcium, sodium, copper, and zinc in raw walnut were observed to significantly increase with boiling while that of carbohydrate, ash, moisture content, phosphorus, potassium, manganese and iron significantly decreased with boiling. Though, the mean levels of P, Ca and K were affected by boiling but were not significantly different to levels obtained in the raw while that of magnesium remained the same in both raw and boiled walnut. The increase observed in the levels of protein, fat, nitrogen, calcium, sodium, copper and zinc perhaps could be due to their release from their bounded forms. It is noteworthy that during the process of boiling, many membrane bounded enzymes could be released and some proteins could undergo denaturation, which might lead to the release of nitrogen and increase protein content. In addition, some mineral salts could decompose into their mineral compositions during the process of boiling and also boiling could cause leaching of nutrients from the hard outer shell into the seeds.

The reduction encountered in the level of P, K, Mn, and Fe by boiling may be an aftermath of the decomposition of their mineral salt by heat which caused a concentration gradient and their consequent loss into the boiling water. This may be responsible for the decrease observed in the percentage of ash in the cooked walnuts. In a similar study, only the levels of crude fat and carbohydrate were decreased with a proportion of 59 and 18%, respectively, while the levels of moisture content (93.5%), protein (21.7%) and fibre (50%) increased but ash content remained the same after cooking [10]. There is limited literature on walnuts to compare the present results with, but when compared with Udedi *et al.* [10], only increased in protein and decreased in carbohydrate level upon cooking corroborated while the rest of the proximate composition were not in agreement. However, for studies on other nuts, Abdusalami and Sheriff [26] also observed increased protein, fat and a reduction in carbohydrate and ash content in Bambara groundnut as obtained in the present study but with a slight increase in Ca, Fe, and Mg.

Evaluating the adequacy of nutrients in 100g of raw and cooked walnuts using RDA values [27] showed that among the proximate composition, only fat content in both raw and cooked walnuts met the daily recommended dietary requirement/intake while the rest were inadequate but with appreciable level of protein, which accounted for 30% of estimated average requirement. The levels of macro minerals were moderate as previously mentioned providing about 50% of daily average requirement in 100g except for Na and K. Therefore, walnut is a good source of P, Ca, and Mg for maintaining strong bones and teeth. More importantly, the levels of micro minerals, except Zn, in raw and cooked walnuts could cater for daily average requirements in 100g of walnut per day and they are all within safe limit [28]. The level of micro mineral contents obtained in the present study indicates its potential as source of co-factors for many enzymes and proteins involving in cell regulation and metabolism, and also, as a rich source of Fe, it can prevent anaemic conditions. The level of crude fat content obtained in both raw and cooked walnuts in the present study and previous studies qualified it as an oil rich plant [29, 30]. Fat is an alternative source of energy during glucose depletion in the body, it also helps in absorption and storage of fat soluble-vitamins and development of tissues and cell wall but high intake of unsaturated fat could lead to heart problems [31, 32]. The inadequate level of zinc obtained in 100g of walnut assessed for daily dietary requirement necessitates bio-fortification of the walnuts with zinc as a limiting micro-mineral, which may increase its utilization as snack among pregnant and child-bearing age women. The relationships among the nutrients are useful for any bio-fortification objectives, for example, the strong positive relationships among Ca, N and zinc could

be explored for nutrient improvement in walnut. Bio-fortification of walnut with any of these minerals could bring a corresponding increase in the other two minerals.

Conclusions

The result of the present study revealed that both raw and cooked walnut seeds collected in Ijebu-Ode LGA and its environs contained appreciable level of protein, phosphorus (P), magnesium (Mg), calcium (Ca), iron (Fe), manganese (Mn) and copper (Cu) in 100g, which the body requires for proper growth, cell functions and metabolism. The study also showed that walnut seeds are rich in crude fat, which may qualifies it as an oil rich plant. Low level of moisture content of the seeds showed that they might possess long shelf life. The results of the nutrient composition revealed that both the cooked nuts (as snack) and raw nuts (perhaps as concoction) are good sources of some minerals and therefore can be used to combat mineral deficiencies in Nigeria. In addition, walnut contains low levels of sodium (Na), potassium (K) and carbohydrate and therefore, is beneficial in hypertensive and diabetic conditions as snack and could be a limiting source in their restricted diets. The present study suggests future bio-fortification of walnut with zinc, which perhaps may bring about co-increase in the limiting minerals such as Ca and richer protein content. Also important is the characterization of its fat composition to enable its maximum utilization for improved health. Therefore, the present study was able to provide detailed nutrient composition and health benefits of eating walnut as snack.

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