ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2019; 19(4): 14848-14862 DOI: 10.18697/ajfand.87.16980

EFFECTS OF DIFFERENT PROCESSING METHODS ON NUTRIENT AND ANTI-NUTRIENT COMPOSITIONS OF AFRICAN STAR APPLE *(Chrysophyllum albidum)* KERNELS

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Volume 19 No. 4
November 2019
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ISSN 1684 5374

ABSTRACT

Effect of different processing methods on nutrients and anti- nutrient compositions of African star apple (*Chrysophyllum albidum*) kernels were investigated. Raw African star apple kernels were collected for the study. Four different processing methods (boiling, fermentation, soaking and roasting) were carried out. All the processed kernels were milled and taken to the laboratory for proximate, amino acids, minerals, vitamins and phytochemical analyses. Results of the study show that raw African star apple kernel contains 93.21 %dry matter, 12.03 % crude protein, 7.10 % crude fibre, 1.45 %ether extract, 1.85 %ash and 70.78 % nitrogen free extract and very high in gross energy (4000.10 Kcal/kg). Processing significantly reduced ($P<0.05$) crude protein in all the methods except boiling (13.26 %). Boiling and roasting significantly increased the energy content of the kernels. All the processing methods significantly ($P<0.05$) increased the contents of all the amino acids analyzed except leucine and lysine. Boiling, fermenting and soaking significantly ($P<0.05$) reduced the contents of leucine and lysine. Also, processing significantly affected the mineral contents of the African star apple kernels ($P<0.05$). All the processing methods except soaking reduced iron content in the kernel. The phosphorus content of the kernel (2.98-3.09 mg/100g) was not significantly affected by any of the processing methods. The results of the vitamin composition showed that only thiamine, riboflavin and ascorbic acid were significantly influenced ($P<0.05$) by the different processing methods. The other vitamins (retinol, cholecalciferol, α-tocopherol and menadione) were not significantly affected by any of the processing methods. Raw kernel was found to contain anti-nutritional factors such as saponin (5.00 mg/100g), tannin (7.33 mg/100g), oxalate (12.41 mg/100g) and phytate (10.06 mg/100g). Anti-nutritional factors were significantly reduced ($P<0.05$) by the processing methods although boiling gave the highest percentage reduction of anti- nutritional factors (saponin, 93.40 %, tannin, 91.68 %, oxalate, 87.51 % and phytate, 98.31 %). It was concluded that African star apple kernel should be processed through boiling before being used as livestock feed.

Key words: African star apple, kernels, nutrient, anti-nutrient, processing, raw

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INTRODUCTION

African star apple (*Chrysophyllum albidum*), a wildly grown plant in the South Western part of Nigeria belongs to the family of trees known as *Sapotaceae*. It is commonly known as "*Agbalumo*" or "*Osan*" (Yoruba) or "*Udara*" (Igbo) in the local languages. Its fruit which is pale yellow with pink coloured endocarp is relished by both children and adults when in season. Its fully ripe fruit becomes available from January through March in the South Western part of Nigeria. The pink-coloured pulp and the whitish cover of the brown-coloured seeds of the fruit are consumed, while the empty pale-yellow pericarp and the seeds are discarded [1].

Nutritionally, *Chrysophyllum albidum* seeds have been reported to contain 14.66 % moisture, 10.13% crude protein, 1.22 % crude fibre, 9.72 % lipid and 7.25 % ash [1]. However, presence of anti-nutritional factors restricts its use by interfering with digestion of carbohydrates and proteins. Phyates, oxalates, saponin and polyphenols form insoluble complexes with essential dietary components like vitamins and minerals rendering them unavailable to the body [1]. Studies have, however, shown that processing can be used to reduce anti-nutritional substances [2,3]. Different traditional processing methods such as roasting, cooking, soaking and fermenting were reported to reduce anti-nutritional factors and raise bio-availability of nutrients in pigeon pea (*Cajanus cajan*) seed meal [2], Flamboyant tree seed meal [4], Tallow (*Detarium microcarpum*) seed meal [3] and *Daniella oliveri* seed meal [5]. This study was carried out to determine the effect of different processing methods on nutrient and anti-nutrient compositions of African star apple kernel with a view to providing preliminary information towards effective utilization of this kernel in livestock feed.

MATERIALS AND METHODS

Experimental site

This experiment was carried out at the Teaching and Research Laboratory, Department of Animal Production, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger State, Nigeria. Minna is located within latitudes 4°30' 09°30' and 09°45'N and longitudes 06° 30' and 06°45 'E with an altitude of 1475 m above sea level [6]. The area falls within the southern guinea savannah vegetation zone of Nigeria with average annual rainfall of between 1100 and 1600 mm and a mean temperature of between 21°C and 36.5°C [6]. Minna experiences two distinct seasons (dry, from November to March and wet or rainy season, from April to October) [6].

Sample collection and preparation

The seeds of African star apple used for this research were collected from farmers in Osogbo, Osun State, Nigeria. The seeds were washed thoroughly with water, sun dried for 24 h at 30°C and dehulled to expose the mesocarp (kernel). The mesocarp was divided into 5 batches as follows:

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(1). Raw
One kilogram of African star apple kernels was air-dried at 25 °C for 3-d, milled using a hammer mill with a sieve size of 3 mm and labeled as raw African star apple kernel meal.

(2). Fermentation
One kilogram of African star apple kernel was fermented in water for 72 h at the rate of 1 kilogram kernel to 5 litres of water as described by Agbabiaka *et al.* [1]. Kernels were poured into a jute bag and immersed inside the water and covered for 72 h. Thereafter, the jute bag was removed and the fermented kernels were air dried for three days at 25 °C. The kernels were later milled using hammer mill with a sieve size of 3mm and labeled as Fermented African star apple kernel meal (FASAKM).

(3). Roasting
One kg of African star apple kernel was roasted at 70 °C for 30 minutes using firewood with iron pot mixed with sand according to the method described by Sola-Ojo *et al*. [7]. During roasting, the kernels were stirred continuously to ensure uniform roasting and to prevent charring until the kernels turned crispy brown. The roasted kernels were then spread out to cool after which they were milled into roasted African star apple kernel meal (RASAKM) using a hammer mill with a sieve size of 3 mm.

(4). Soaking
One kilogram of African star apple kernel was soaked in cold water for 24 h at the rate of one kilogram kernel to five litres of water as described by Sotolu and Faturoti [8] and Saulawa *et al.* [9]. Thereafter, water was drained off by means of 10mm sieve and the soaked kernels were air dried at 25 °C for three days. The dried kernels were later milled using 3mm a hammer mill and labeled as Soaked African star apple kernel meal (SASAKM).

(5). Boiling
One kilogram of African star apple kernel was subjected to boiling at 100 °C for 15 minutes at the rate of 1 kilogram kernel to 5 litres of water as described by Ahamefule *et al.* [2] and Jimoh *et al.* [10] after which water was drained off using 10 mm sieve and the boiled kernels were air dried at 25 °C for three days. The dried kernels were milled using a 3 mm hammer mill and labeled as Boiled African star apple kernel meal (BASAKM).

Samples were subjected to laboratory analysis to determine the nutrient and anti-nutrient compositions according to AOAC [11] at the Animal Science Laboratory, University of Ibadan, Oyo State. The gross energy was determined using Gallenkamp Ballistic Bomb Calorimeter (Model 1266, Parr Instrument Co., Moline, IL.) with benzoic acid as an internal standard.

The amino acids were quantitatively measured by the procedure of Benitez [13] using Applied Biosystems PTH automated amino acid analyzer (Technicon Sequential Multi-sample Analyzer, TSM, (40405), Model 120A, Version 1.4B, USA). Sample was

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hydrolyzed for determination of all amino acids except tryptophan in consistent boiling hydrochloric acid for 22 h under a nitrogen flush.

Data Analysis

Data generated were subjected to Analysis of variance (ANOVA) using the general linear model of statistical analysis system, Version 9.3 [14]. Significance was accepted at $P < 0.05$.

RESULTS AND DISCUSSION

Proximate composition

The results of the proximate composition of raw and differently processed African star apple kernel are shown in Tables 1. There were significant differences (P<0.05) between raw and differently processed African star apple kernels for all the components considered on dry matter basis. The crude protein (CP) of boiled kernel was significantly higher (P<0.05) than that of other processing methods. Soaked kernel recorded the least CP (P<0.05). However, ether extract and ash contents were significantly higher in soaked kernel (P<0.05) than that of other processing methods. The gross energy of boiled, fermented and roasted kernels was similar (P>0.05) and higher than that of raw and soaked kernels. Metabolizable energy of raw, boiled and roasted kernel was not significantly different (P>0.05). The crude protein values ranged from 8.08 % (DM) for fermented kernel to 13.26 % (DM) for boiled kernel. The crude protein value of 12.03 % observed in this study was higher than 10.13 % as reported by Agbabiaka *et al.* [1] for raw star apple kernel. However, the value of 8.08 % CP observed for fermented star apple was lower than 14.49 % CP as reported by Agbabiaka *et al.* [1]. The value of 10.81 % CP observed in this study for roasted star apple kernel is similar to 10.95 % CP as reported by Jimoh *et al.* [10] for roasted star apple seed. The differences in these values may be attributed to variation in soil, climate, variety or processing methods. It was also observed that only boiling improves the crude protein content of the kernels. Saulawa *et al.* [9] had earlier reported that boiling gave the best result when baobab seeds were processed with different methods (boiling, toasting, soaking, soaking and boiling and sprouting). The lowest CP content (7.95 %) was observed in soaked star apple kernel. The reduction in crude protein from 12.03 % to 10.95 % observed in the roasted Star apple kernels in this work is in agreement with previous findings [15, 16]. This may be partly due to the burning off of some nitrogenous compounds during roasting [16]. However, Emiola *et al.* [17] reported an increase in crude protein content of raw kidney beans when subjected to roasting. The crude fibre value ranged from 5.10 % for roasted to 7.10 % for raw kernels. The crude fibre contents of all samples were lower than that of the raw sample possibly because some seed coats were lost during the processing period. The crude fibre values observed in this study were higher than 1.22 % and 1.19 % reported by Agbabiaka *et al.* [1] for raw and fermented kernels respectively. On the other hand, fermentation significantly reduced ether extract content from 1.45 % (raw) to 1.38 % (fermented). This may be attributable to solubilization and leaching of some nutrient content of the kernel as a result of the water treatment [18]. Ether extract content was however improved through soaking. The nitrogen free extract (NFE) values ranged from 71.57 % for boiled kernels to 74.82 % for fermented kernels. These values are

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higher than the range of 51.04 to 69.45 % recorded for fermented and raw kernels, respectively [1]. Also, Abdullahi [19] reported a range of 76.37- 79.85 % NFE for differently processed mango seed kernels. This is an indication that African star apple kernel contained a moderately high level of calorie compared to some conventional feedstuff. The Metabolizable energy (ME) values ranged between 3059.70 Kcal/kg ME for soaked kernels to 3163.37 Kcal/kg ME for roasted kernels. The ME values observed in this study showed that the sample has an energy concentration that is comparable with maize (3400 Kcal/kg ME). The values for ME also compare favourably well with those reported by Aduku [20] for some energy feedstuff such as Guinea corn (3300 kcal/kg), millet (2984 kcal/kg) and cassava meal (3035 kcal/kg).

Amino acid composition

The results of the amino acid composition of raw and differently processed African star apple kernel are shown in Table 2. The results show that there were significant differences (P<0.05) in all the amino acids analysed except phenylalanine, cystine and serine. The methionine, tryptophan, arginine, histidine and threonine contents of boiled, roasted and soaked were not significantly different (P>0.05). The least methionine and tryptophan contents were observed in raw kernels. Arginine was the most concentrated (6.83 mg/100 g crude protein) essential amino acid while glutamic acid was the most concentrated non-essential amino acid (7.29 mg/100 g) in the raw African star apple kernel. The value of leucine (5.37 mg/100g) obtained in this study for raw kernel compares favourably with values of 5.17 mg/100g reported by Gbago *et al.* [21] on studies of Monkey Apple (*Anisophyllea laurina R. Br. ex Sabine*) seed. Glutamic and aspartic amino acids made up (13.61 mg/100 g protein) as the most abundant non-essential amino acids in the raw kernel. This confirms the reports by some workers [22, 23] that glutamic and aspartic acids are the most abundant amino acids in some Nigerian plants. The least concentrated essential amino acid is methionine (0.99 mg/100 g) while ornithine (0.22 mg/100g) is the least concentrated non-essential amino acid protein in the raw sample. All the processing methods significantly (P<0.05) increased the contents of all the amino acids analyzed except leucine and lysine. Boiling, fermenting and soaking significantly (P<0.05) reduced the contents of leucine and lysine in this study. Aremu *et al.* [24] had earlier reported that transamination and deamination reactions might be responsible for the slight changes in the amino acid profiles of raw and processed red kidney bean seed flours. The authors observed that as heating proceeds in boiling, protein quality increases to a maximum before declining again with continued heating; thus reduction is likely to be related to increasing Maillard browning causing lysine to be rendered unavailable [24]. The other amino acids (phenylalanine, cystine and serine) were not significantly affected by the processing methods.

Mineral and Vitamin Compositions

The results of the mineral and vitamin compositions of raw and differently processed African star apple kernel are shown in Tables 3. There were significant differences (P<0.05) in all the minerals analysed except phosphorus. The potassium content of roasted kernel was significantly higher (P<0.05) than that of other processing methods. Boiled kernel has higher concentration of sodium (P<0.05) than that of other methods. The zinc content of roasted kernel was significantly lower than that of other methods

(P<0.05). The most abundant minerals in the raw kernel sample were potassium (551.00 mg/100 g) and sodium (41.00 mg/100 g), while the least concentrated mineral was manganese (0.2 mg/100 g). The kernels of African star apple were also rich sources of the following nutritional valuable minerals: Ca (20.65 mg/100 g) and Fe (2.59 mg/100 g). The concentrated values of phosphorus (2.98 mg/100 g), calcium and iron would make African star apple kernel suitable for bone formation in livestock. The value for sodium in the raw kernel (41.00 mg/100 g) is similar to the value of 43.33 mg/100g reported as a mean for three different varieties of African star apple fruits studied by [25]. Furthermore, the results of this study confirm the report of Agbabiaka *et al.* [1] that potassium is the most abundant mineral in African star apple kernel followed by sodium, copper was however found to be least concentrated. Processing significantly affected the content of some minerals in the kernel (P<0.05). All the processing methods except soaking reduced iron content in the kernel. The phosphorus content of the kernel was not significantly affected by any of the processing methods. Phosphorus is always found with calcium in the body, both contributing to blood formation and supportive structure of the body [26]. Modern foods rich in animal protein and phosphorus can promote the loss of calcium in urine [27]. Also, sodium and potassium are required for the maintenance of osmotic balance of the body fluids, the pH of the body to regulate muscles and nerves irritability, control glucose absorption and enhance normal retention of protein during growth [27].

The result of the vitamin composition of raw and differently processed African star apple kernel shows that only thiamine, riboflavin and ascorbic acid were significantly different (P<0.05). The other vitamins (retinol, cholecalciferol, alpha-tocopherol and menadione) were not significantly affected by any of the processing methods. Processing significantly (P<0.05) reduced the thiamine, riboflavin and ascorbic acid content of the kernels.

Phytochemical Composition

The results of the phytochemical composition of raw and differently processed African star apple kernel are shown in Tables 4. There were significant (P<0.05) differences between the raw and processed Kernels in all the parameters measured. The percentage reduction of saponin, tannin, oxalate and phytate was significantly (P<0.05) higher in boiled kernels than that of other methods. There was a general reduction in the content of anti-nutritional factors (saponin, tannin, oxalate and phytate) as a result of processing of raw African star apple kernels, though this reduction varies in degree with different processing techniques. The highest percentage reductions in saponin (93.40 %), tannin (91.68 %), oxalate (87.51 %) and phytate (98.31 %) were observed when the raw African star apple kernels were boiled followed by roasting and soaking. Fermentation gave the least percentage reduction of anti-nutrients. The higher percentage reduction of all parameters observed in boiling in this trial confirms earlier report by other authors [9, 19, 28] that boiling method was very effective in reducing anti-nutrients in Mango seed kernels, Baobab seed and Amadumbe (*Colocasia esculenta*) than any other processing methods.

All parameters observed in this study for raw kernels differ from what was earlier reported by Agbabiaka *et al.* [1] who observed that raw kernels contain 0.48 mg/100g

DOI: 10.18697/ajfand.87.16980

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ISSN 1684 5374

tannin and 12.37 mg/g phytate. The variation could be due to reasons reported by Mohamed *et al*. [29] that species may vary not only in composition of nutrient but in type and amount of toxins, thus results obtained with one species may not necessarily be applicable to another. Even the length of storage time will also affect certain characteristics. The apparent decrease in the content of phytates during boiling may be partly due to leaching into the boiling medium or degradation by heat or the formation of insoluble complexes between phytates and other components such as phytate-proteins and phytate-protein-mineral complexes [30]. Reduction of phytate is expected to enhance the bioavailability of proteins and dietary minerals of the kernels.

CONCLUSION

Results from this study have shown that the proximate, amino acids, minerals, vitamins and phytochemical compositions of raw and differently processed African star apple kernels differ significantly ($P<0.05$). The Processed kernels were found to contain higher amounts for nutrients compared to the amounts contained in the raw kernels. This study has revealed that African star apple kernels could be used more as feed ingredient in animal feed, judging from the high carbohydrate, adequate protein and low lipid content. Addition of amino acid rich ingredients would compensate for the low amino acid contents of the kernel. This study also shows that the studied anti-nutrients, though showing a significant concentration in raw kernels, should not pose a problem in animal feed if the kernels are properly processed [31]. Anti-nutritional factors were significantly reduced ($P<0.05$) by the processing methods although boiling gave the highest percentage reduction of anti-nutritional factors and increased crude protein content. It is recommended that African star apple kernel should be processed through boiling before being used as animal feed. Further research should be conducted on performance response of animals to African star apple kernel diets since chemical analysis alone should not be the sole criterion for judging the nutritional importance of a particular feed ingredient.

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Table 1: Proximate Composition of raw and differently processed African star apple kernels

Nutrients, %	Raw	Boiled	Fermented	Roasted	Soaked	SEM	P-value
Dry matter	93.21[a]	92.83[b]	93.07[a]	93.09[a]	92.40[c]	0.08	0.0012
Crude Protein	12.03[b]	13.26[a]	8.08[d]	10.81[c]	7.95[d]	0.26	0.0001
Crude fibre	7.10[a]	5.20[c]	6.20[b]	5.10[c]	6.00[b]	0.18	0.0036
.Ether extract	1.45[bc]	1.55[bc]	1.38[c]	1.70[b]	1.97[a]	0.10	0.0122
Ash	1.85[c]	1.25[e]	2.60[b]	1.55[d]	3.11[a]	0.10	0.0001
Nitrogen free extract	70.78[c]	71.57[c]	74.82[a]	73.93[ab]	73.38[bc]	0.39	0.0029
Gross energy (Kcal/kg)	4000.10[b]	4010.20[a]	4010.19[a]	4010.21[a]	4000.11[b]	0.02	0.0001
Metabolizable energy (Kcal/kg ME)	3147.23[a]	3157.96[a]	3067.36[b]	3163.37[a]	3059.70[b]	8.96	0.0002

*All values are means of triplicate determinations expressed in dry weight basis. abc= means with different superscripts on the same row are significantly different ($P<0.05$), SEM= Standard error of mean, P = Probability value. NFE: Nitrogen Free Extract =100-(%CP+%CF+%EE+%Ash).

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Table 2: Amino acid Composition of Raw and differently processed African star apple kernels

Amino acid (mg/100g)	Raw	Boiled	Fermented	Roasted	Soaked	SEM	P-value
Essential Amino acids							
Methionine	0.99^{c}	1.37^{a}	1.16^{b}	1.27^{ab}	1.28^{ab}	0.04	0.0034
Tryptophan	1.20^{c}	1.81^{a}	1.51^{b}	1.81^{a}	1.64^{ab}	0.09	0.0056
Lysine	2.72^{b}	2.25^{c}	2.07^{c}	3.04^{a}	2.17^{c}	0.09	0.0005
Leucine	5.37^{a}	4.17^{b}	3.71^{c}	5.28^{a}	4.10^{b}	0.12	0.0001
Arginine	6.83^{b}	7.15^{a}	6.48^{c}	6.21^{d}	7.38^{a}	0.06	0.0001
Valine	2.83^{a}	3.28^{b}	1.89^{c}	2.95^{a}	2.19^{b}	0.10	0.0006
Isoleucine	2.61^{a}	2.28^{b}	2.71^{a}	2.75^{a}	2.08^{b}	0.16	0.0062
Histidine	1.57^{b}	1.68^{ab}	1.40^{c}	1.75^{a}	1.61^{ab}	0.06	0.0102
Threonine	2.21^{a}	2.08^{ab}	1.92^{b}	2.32^{a}	2.17^{a}	0.06	0.0095
Phenylalanine	3.24	3.69	3.42	3.50	3.55	0.32	0.6985
Non-Essential Amino acids							
Proline	2.16^{d}	2.88^{a}	2.60^{bc}	2.46^{c}	2.81^{ab}	0.09	0.0033
Glycine	3.35^{a}	2.16^{b}	2.88^{bc}	2.72^{c}	3.05^{ab}	0.12	0.0225
Alanine	3.05^{b}	3.27^{a}	2.85^{c}	3.17^{a}	3.19^{a}	0.04	0.0008
Cystine	1.38	1.51	1.24	1.52	1.37	0.09	0.1190
Tyrosine	2.85^{b}	3.26^{a}	2.93^{b}	2.86^{b}	3.14^{a}	0.05	0.0011
Ornithine	0.22^{a}	0.24^{a}	0.12^{b}	0.24^{a}	0.20^{ab}	0.04	0.0455
Serine	2.87	3.13	2.86	3.15	3.08	0.19	0.0581
Amino butyric acid	0.52^{b}	0.68^{a}	0.37^{c}	0.58^{b}	0.54^{b}	0.03	0.0021
Aspartic acid	6.32^{c}	6.77^{a}	5.23^{d}	5.25^{d}	6.60^{b}	0.03	0.0001
Glutamic acid	7.29^{d}	8.91^{a}	7.16^{e}	8.35^{c}	8.65^{b}	0.02	0.0001

*All values are means of triplicate determinations. abc= mean with different superscripts on the same row are significantly different (P<0.05), SEM= Standard error of mean, P = Probability value

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Table 3: Mineral and Vitamin Compositions of raw and differently processed African star apple kernels

Minerals (mg/100g)	Raw	Boiled	Fermented	Roasted	Soaked	SEM	P-value
Sodium	41.00^{d}	42.90^{a}	41.70^{c}	42.00^{b}	41.05^{d}	0.09	0.0021
Potassium	551.00^{e}	592.61^{c}	604.94^{b}	657.00^{a}	568.10^{d}	0.35	0.0008
Phosphorus	2.98	3.00	3.08	3.04	3.09	0.12	0.0561
Calcium	20.65^{b}	22.00^{ab}	21.03^{b}	23.11^{a}	23.80^{a}	0.78	0.0012
Manganese	0.20^{b}	0.60^{a}	0.26^{b}	0.30^{b}	0.60^{a}	0.10	0.0001
Iron	2.59^{a}	1.56^{b}	1.36^{b}	1.88^{b}	3.10^{a}	0.87	0.0008
Zinc	3.71^{a}	3.98^{a}	3.51^{a}	2.98^{b}	4.30^{a}	0.33	0.0032
Copper	1.20^{bc}	1.75^{ab}	1.60^{b}	2.04^{a}	1.90^{ab}	0.21	0.0061
Vitamins							
(mg/100g)							
Thiamin	0.38^{a}	0.20^{c}	0.30^{b}	0.13^{d}	0.33^{ab}	0.02	0.0005
Riboflavin	0.14^{a}	0.05^{cd}	0.08^{bc}	0.03^{d}	0.11^{ab}	0.01	0.0052
Ascorbic acid	5.48^{a}	2.95^{d}	3.53^{c}	2.06^{e}	4.28^{b}	0.02	0.0001
Retinol	0.19	0.17	0.17	0.19	0.18	0.01	0.0599
Cholecalciferol	0.06	0.05	0.06	0.07	0.05	0.01	0.0675
ά-tocopherol	0.07	0.06	0.07	0.08	0.06	0.01	0.0512
Menadione	0.02	0.02	0.02	0.03	0.02	0.01	0.0671

*All values are means of triplicate determinations. abc= mean with different superscripts on the same row are significantly different (P<0.05), SEM= Standard error of mean, P = Probability value

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ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 4: Phytochemical Composition of raw and differently processed African star apple kernels

Antinutrients, mg/100g	Raw	Boiled	Fermented	Soaked	Roasted	SEM	P-value	*Critical level
Saponin	5.00[a]	0.33[d]	2.02[b]	1.33[c]	0.35[d]	0.06	0.0001	7.02
% Reduction		93.40	59.60	73.40	93.00			
Tannin	7.33[a]	0.61[e]	4.02[b]	3.10[c]	1.08[d]	0.37	0.0001	31.20
% Reduction		91.68	45.16	57.71	85.27			
Oxalate	12.41[a]	1.54[e]	5.00[b]	4.67[c]	2.00[d]	0.09	0.0001	2.50
% Reduction		87.51	59.45	62.37	83.88			
Phytate	10.06[a]	0.17[d]	3.33[b]	1.67[c]	0.17[d]	1.17	0.0001	0.50
% Reduction		98.31	66.89	83.39	98.31			

*All values are means of triplicate determinations. abc= means with different superscripts on the same row are significantly different (P<0.05), SEM= Standard error of mean, P = Probability value

ACKNOWLEDGEMENTS

The authors acknowledge the financial support received from TETFUND/FUTMINNA /2016-2017/6THBRP/06 which made it possible to carry out this study.

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