International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 01-06-2024, Accepted: 22-06-2024, Published: 16-07-2024
Volume 9, Issue 3, 2024, Page No. 7-12

Effect of boiling and roasting on the nutrient and anti-nutrient composition of African Elemi (*Canarium Schweinfurthii*)

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Abstract
This study evaluated the effect of boiling and roasting on the nutrient and anti-nutrient composition of African elemi (Canarium schweinfurthii). African elemi fruits were sorted, cleaned, and then divided into three potions. The first portion was raw and it served as the control. The second was boiled for 20 min while the remaining portion was roasted in a hot air oven at 120ºC for 20 min. The control sample was analyzed raw without any treatment. Proximate, mineral and anti-nutrient composition of the samples were determined. Boiling increased the moisture content of the samples which ranged from 4.88-11.95%, ash content ranged from 2.61-2.64% and recorded no significant difference ($p<0.05$). The fat, crude protein and crude fibre contents of the African elemi reduced ranged from 1.97-2.84%, 19.74-21.78% and 7.99-9.29% respectively, while the carbohydrate content ranged from 63.51-69.62%. Mineral composition of the samples ranged from 220.95-245.50 mg/100g for calcium, 152.00-218.06 mg/100g for potassium, 13.10-13.27 mg/100g for iron, 3.73-6.05 mg/100g for zinc and 40.56-44.16 mg/100g for magnesium while the anti-nutrient composition ranged from 2.22-8.07 mg/kg, 3.45-18.09 mg/g and 121.16-429.30 mg/100g for oxalate, tannin and phytate respectively. Results showed that that boiling and roasting reduced the crude fibre, crude protein and fat content of the sample while increasing the carbohydrate content. The calcium, potassium and zinc content of the sample increased while and the anti-nutrient composition reduced and were within permissible limit. This study recommends roasting and boiling as suitable methods for the processing of African elemi with better mineral constituents and reduced anti-nutrients. Further studies should be focused on investigating the amino acid profile, mineral bioavailability and protein digestibility of the processed African elemi fruits.

Keywords: African elemi, Nutrient composition, Anti-nutrient, Boiling, Roasting

Introduction

African elemi (*Canarium schweinfurthii*) is a large tropical tree which belongs to the family of *Burseraceae* [1]. The fruit is commonly found in large quantity in Pankshin, Plateau State of Nigeria and is also produced in similar quantities in other states of the northern and south-eastern Nigeria. In Nigeria, the fruit is called "ube mgba‟ in Igbo and "atili" in Hausa. The fruits contain single triangular-shaped seed with small projections at the three edges. The seeds are embedded in a purplish green pulp which is oily and edible, with a desirable sweet but not too sugary taste similar to that of avocado pear [2]. The pulp oil is about 71 % palmitic acid and 18 % oleic acid. The seed-kernel is oily and edible too. They contain several fatty acids including oleic (36%), linoleic (28%), palmitic (26%), and 7% stearic [3]. Whole seeds and pulp of African elemi have been used as medicinal remedies, as source of vitamin C and as flavour in snacks and non-alcoholic beverages [3].

African elemi can be eaten raw or softened in warm water to improve palatability. The seed of this plant however, which contains the kernel oil is either thrown away or used as local beads for feet [4]. Maduelosi and Angaye [3] reported the pulp to contain 26.09% moisture, 3.31% ash, 30.56% crude fat, 0.78% crude fibre, 19.31% crude protein, and 20.05% carbohydrate thereby suggesting that the pulp of African elemi can serve as a good source of essential nutrients for humans.

In Nigeria, the underlying causes of malnutrition are inadequate food production, poor processing method and poverty. Several factors influence the nutritional content of food and one is the method utilized for processing [5]. The primary purpose of processing is to render food palatable and develop its aroma, but it has inevitable consequences on the nutritional value of foods. For example, there is some inevitable leaching of nutrients into the boiling water during processing [6]. Processing methods may also improve the digestibility, promote palatability improve keeping quality, and have effect on the major nutrients, including proteins, carbohydrates, minerals and vitamins [7].

Cooking has been known to bring about high complex reaction without having direct effect on the nutritional value of food [8]. Boiling is the most common method of cooking and is also the simplest. During boiling, the action of heated water makes the food to get cooked. The liquid is usually thrown away after the food is cooked. Roasting is a cooking method that uses dry heat, whether an open flame, oven or other heat source. Roasting usually cause caramelization or milliard browning of surface of the food, which is considered flavour enhancement [8]. Roasting uses more indirect, diffused heat (as in oven), and is suitable for slower cooking of meat in a larger, whole piece. With careful control of cooking methods, nutrient losses can be minimized without affecting palatability and much nutrient loss. It is therefore the objective of this study to determine the effect of cooking methods (boiling and roasting) on the nutrient composition, anti-nutrient, and oil quality of African elemi.

African elemi pear has considerable nutritional value that makes it a useful supplement to human food. However, its nutritional significance is often vitiated by the presence of anti-nutritional factors [9]. Successful application of African elemi in modern food products is hinged on a thorough understanding of its anti-nutritional factors and how processing methods could reduce these anti-nutrients while increasing nutrient levels.

Materials and Methods

The fruits of African elemi (*Canarium schweinfurthii*) were purchased from Obolo market in Nsukka, Enugu State, Nigeria. Chemicals and equipments used were of analytical grade and obtained from the Food Analysis Laboratory, Department of Food Science and Technology, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Rivers State, Nigeria.

1. Sample Preparation

As shown in fig. 1, the African elemi fruits were sorted, cleaned, and then divided into three potions. The first portion was raw and it served as the control. The second was boiled for 20 min while the remaining portion was roasted in a hot air oven at 120ºC for 20 min. For the boiling, the African elemi was boiled in a pot with tap water in a ratio of 1:3 (weights of the seeds to three parts of water) for varying periods of 20 min. The control sample was analyzed raw without any treatment. The pulps after cooking were separated from the seeds and stored in a labelled Ziplock bags in a cool dry place until used for various analysis.

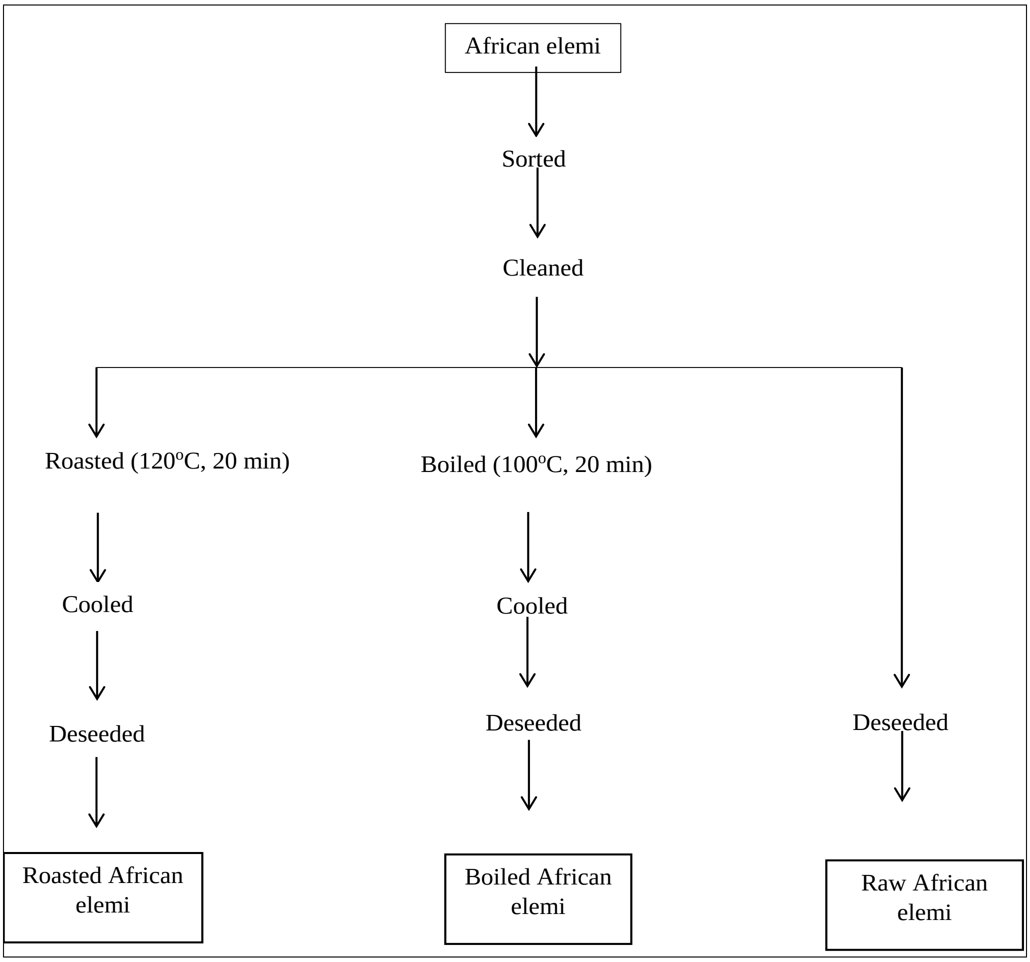

Fig 1: Processing of African elemi using boiling and roasting methods

2. Determination of the proximate composition of processed and unprocessed African elemi

The moisture, crude protein, crude fibre, crude fat and total ash contents of samples were analysed using the method described by Association of Official Analytical Chemists [10]. Moisture was obtained gravimetrically after drying to a constant weight at 70oC in a hot air oven (DHG 9140A). Fat was determined using soxhlet extraction method with ethyl ether. Kjeldahl method and a nitrogen conversion factor of 6.25 was used for crude protein determination. Ash content was determined gravimetrically after the incineration of the samples in a muffle Furnace (Model SXL) at 550ºC for 2 h. Enzymatic gravimetric method was utilized in the determination of crude fibre. Carbohydrate was calculated by difference {100 - (Crude protein + crude fibre + ash + fat)}.

3. Mineral content determination

As described by Gbadamosi *et al.* [11], 1 g of each sample was digested with 10% HNO_3 after ashing. The sample was filtered after digestion and the filtrate was made up to 100 mL of distilled deionized water. Atomic Absorption Spectrometer was used to determine the concentration of Calcium, Iron, Potassium, Zinc and Magnesium.

4. Anti-nutrient determination

Determinations of phytate, oxalate and tannin contents were done by Colorimetric, Titration and Folin Denis Colorimetric methods respectively as described by Nbaeyi-Nwaoha and Onwuka [12].

5. Statistical analysis

All the analysis was carried out in duplicate. Data obtained was subjected to Analysis of Variance (ANOVA). Difference between means was evaluated using Turkey's multiple comparison tests with 95% confidence level. The statistical package SPSS software version 26 was used.

Results and Discussions

Table 1: Proximate composition (%) of processed and unprocessed African elemi

Samples	Moisture	Ash	Fat	Crude protein	Crude fibre	Carbohydrate
Raw	$9.23^{b}±0.20$	$2.64^{a}±0.06$	$2.84^{a}±0.16$	$21.78^{a}±0.17$	$9.29^{a}±0.27$	$63.51^{b}±0.35$
Boiled	$11.95^{a}±0.07$	$2.61^{a}±0.69$	$1.79^{c}±0.03$	$19.74^{b}±0.42$	$7.99^{b}±0.02$	$63.91^{b}±0.42$
Roasted	$4.88^{c}±0.44$	$2.61^{a}±0.07$	$2.41^{b}±0.06$	$20.47^{b}±0.35$	$8.38^{b}±0.26$	$69.62^{a}±0.13$

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

1. Proximate composition of processed and unprocessed African elemi

The proximate composition of processed and unprocessed African elemi is shown in Table 1.

The moisture content ranged from 4.88-11.95% with the roasted sample having the lowest, and the highest moisture content recorded by the boiled sample. There was significant difference (P<0.05) between the samples in their moisture content. Roasting reduced the moisture content of the sample, while boiling increased the moisture content. This finding agrees well with the study of Mada *et al.* [13] who reported a decrease in the moisture content of groundnut (4.83-3.20%) following roasting and an increase (4.83-9.43%) after boiling. Moisture content is of significance as it is one of the determinants of shelf-life of processed foods [14]. The moisture content of the differently processed African elemi from this study are low enough to reduce the chance of microbial spoilage to guarantee good storage stability [15]. This study further suggests that the roasted African elemi would keep longer than the boiled and parboiled samples. According to Agoreyo *et al.* [16], low moisture content decreases the perishability and increases the shelf life of the food.

Ash content of the samples was as follows: 2.64%, 2.61% and 2.61% for raw, boiled and roasted samples, respectively. The lowest value (2.61%) was obtained in the boiled and roasted samples while the raw sample had the highest ash content (2.64%). The processed and unprocessed African elemi exhibited similar ash content with no significant (p>0.05) difference observed. This suggest that processing methods had no significant (p>0.05) effect on the ash content of African elemi fruits. The ash content represents the total amount of minerals present in a food [2].

Fat content ranged from 1.79% in the boiled sample to 2.84% in the raw sample. There was a significant (p<0.05) difference in the fat content of the samples. Boiling and roasting resulted in a significant (p<0.05) reduction in the fat content of the samples. The decrease in fat after roasting was also reported by Djikeng *et al.* [17] for walnut seeds. Orisa *et al.* [18] also reported fat decrease in boiled *Irvinga gabonesis* flour.

Crude protein content ranged from 19.74% to 21.78% with the lowest value (19.74%) obtained in the boiled sample while the raw sample had the highest value (21.78%). Boiling and roasting led to a significant (p<0.05) reduction in the crude protein content of the samples. The decrease in crude protein content of the African elemi due to boiling could be attributed to leaching of nutrients such as nitrogen-containing compounds into the cooking water. The observed increase in protein on roasting may be due to progressive loss of moisture with drying [19]. Fagbemi [20] had also reported that decreases of protein content in boiled soybean may be attributed to leaching during boiling process. Protein serves as the major structural components of all cells in the body, and functions as enzymes, transport carriers, and some hormones. Dietary protein is an important macronutrient in human nutrition being the source of essential amino acids for the synthesis of the body 's proteins [19].

Crude fibre content recorded 9.29%, 7.99% and 8.38% for raw, boiled and roasted samples, respectively. The lowest value (7.99%) was obtained in the boiled sample while the raw sample had the highest value (9.29%). Similarly, roasting and boiling led to a significant (p<0.05) reduction in the crude fibre content with the roasting process producing a larger effect than the boiling process. Crude fibre is the amount of indigestible sugars present in a food sample which has the physiological role of adding bulk to stool, and thus contribute to the maintenance of internal distensions for a normal peristaltic movement [21]. By facilitating peristalsis, dietary fibre helps to reduce many gastrointestinal diseases, serum cholesterol, risk of coronary heart disease, colon and breast cancer and hypertension [22].

Carbohydrate content ranged from 63.51-69.62% with the lowest value (63.51%) obtained in the raw sample while the roasted sample had the highest value (69.62%). An increase in the carbohydrate content of the samples was observed upon boiling and roasting. However, only roasting produced a significant (p<0.05) increase. Carbohydrate supplies energy to the body and contributes to fat metabolism, spares proteins as an energy source, act as a mild natural laxative for human beings and generally add to the bulk of the diet.

Table 2: Mineral composition (mg/100g) of processed and unprocessed African elemi

Samples	Calcium	Potassium	Iron	Zinc	Magnesium
Raw	$220.95^{b}±1.95$	$152.00^{c}±2.00$	$13.10^{a}±0.10$	$3.75^{b}±0.25$	$44.16^{a}±0.84$
Boiled	$245.50^{a}±5.50$	$218.06^{a}±1.94$	$13.27^{a}±0.07$	$3.73^{b}±0.16$	$41.02^{a}±0.02$
Roasted	$244.50^{a}±5.50$	$166.20^{b}±2.85$	$13.20^{a}±0.26$	$6.05^{a}±0.65$	$40.56^{a}±1.44$

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

Effect of Processing Methods on the Mineral Composition of Processed and Unprocessed African elemi

The mineral composition of processed and unprocessed African elemi is shown in Table 2.

Calcium content of the samples was as follows: 220.95 mg/100g, 245.50 mg/100g and 244.50 mg/100g for raw, boiled and roasted samples, respectively. The raw sample had the lowest value (220.95 mg/100g) while the boiled sample had the highest value (245.50 mg/100g). There was a significant ($p<0.05$) increase in the calcium content of the samples upon boiling and roasting. Eke-Ejiofor and Onyeso [7] also reported an increase in the calcium content of orange-fleshed sweet potato during boiling from 236.40-280.50 mg/100g. This indicates that roasting and boiling is suitable to improve the calcium content of African elemi. The increase in the calcium content of the samples upon processing could be due to the fact that, the anti-nutritional factors present in the seeds and which were complexed to the mineral were significantly destroyed by heat, leading to the increase in its concentration [23]. The increase observed after boiling could also be due to the fact that during boiling, there was a release of calcium which had been complexed by phytate. Calcium is known as a macro element necessary for the development of teeth, bones and the release of hormones [24].

Potassium content ranged from 152.00 mg/100g to 218.06 mg/100g with the lowest value obtained in the raw sample while the boiled sample had the highest value. There was a significant ($p<0.05$) difference in the potassium content of the samples. An increase in the potassium content was also observed following processing with a larger increase obtained for the boiled African elemi than for roasted sample. Potassium is an electrolyte essential in the homeostatic balance of body fluids. It is needed in fluid balance and regulation of nerve impulse conduction, regular heart beat and cell metabolism [25].

Iron content recorded 13.10 mg/100g, 13.27 mg/100g and 13.20 mg/100g, for raw, boiled, and roasted samples, respectively. The lowest value was obtained in the raw sample while the boiled sample had the highest value. There was also an increase in the iron content following processing. However, no significant ($p>0.05$) difference was observed in the iron content of the processed and unprocessed African elemi. Iron values from this study are within the RDA for iron (7-16 mg/100g) [26].

Zinc content ranged from 3.73 mg/100g in the boiled sample to 6.05 mg/100g in the roasted sample. A significant ($p<0.05$) increase in the zinc content was observed following roasting while boiling led to a reduction. However, the reduction in the zinc content caused by the boiling process was not significantly ($p>0.05$) different from the raw sample. Zinc is an important co-factor for more than 70 enzymes and it plays a central role in cell division, protein synthesis and growth. The deficiency of zinc in complementary foods will result to growth failure, anaemia, enlargement of liver and spleen and impairment of skeletal development [27].

Magnesium content ranged from 40.56 mg/100g to 44.16 mg/100g with the lowest value (40.56 mg/100g) obtained in the roasted sample while the raw sample had the highest value. A reduction in the magnesium content was observed following boiling and roasting. However, no significant ($p>0.05$) difference was observed. Magnesium is a mineral necessary for enzymes using adeonosine triphosphate which contributes to DNA and RNA synthesis during cell proliferation. Magnesium deficiency causes convulsions and irritability.

Table 3: Anti-nutrient composition of processed and unprocessed African elemi

Samples	Oxalate (mg/kg)	Tannins (mg/g)	Phytate (mg/100g)
Raw	$8.07^{a}\pm0.07$	$18.09^{a}\pm0.53$	$429.30^{b}\pm1.80$
Boiled	$2.22^{c}\pm0.13$	$3.65^{b}\pm0.32$	$125.30^{a}\pm0.42$
Roasted	$3.17^{b}\pm0.22$	$3.45^{b}\pm0.27$	$121.16^{a}\pm0.42$
Permissible limit	3-5 mg/kg	20 mg/g	250-500 mg

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p<0.05$).

3. Effect of Processing Methods on the Anti-nutrient composition of processed and unprocessed African elemi

Oxalate content of the samples recorded 8.07 mg/kg, 2.22 mg/kg and 3.17 mg/kg for raw, boiled and roasted samples, respectively. The boiled sample had the lowest value (2.22 mg/kg) while the raw sample had the highest value (8.07 mg/kg). There was a significant ($p<0.05$) reduction in the oxalate content of the African elemi following boiling and roasting. This effect was more in the boiled sample than the roasted sample. The values were within the permissible limit of 3-5 mg/kg for oxalate. The decreases in oxalate content of the samples after boiling were in conformity with the results reported by Ijarotimi *et al.* [28] that boiling reduced the oxalate content of Bambara groundnut seeds. Savage and Martensson [29] reported that when taro samples were boiled in water, oxalate content decreased by at least 47%. Oxalates are known to complex with calcium to form calcium crystals which get deposited as stones that are associated with blockage of renal tubules [30].

Tannin content ranged from 3.65 mg/g to 18.09 mg/g with the lowest value (3.45 mg/g) while the raw sample had the highest value (18.09 mg/g). Similarly, boiling and roasting resulted in a significant ($p<0.05$) reduction in the tannin content of the samples. Tannins are chelating agents for metals and can form complexes with macromolecules. Through this process, essential substrates and enzymes of micro-organisms are depleted leading to cell death [31]. The concentration of tannins recorded in this study for the processed African elemi is within the permissible limit of 20 mg/g.

Phytate content recorded 429.30 mg/100g, 125.30 mg/100g and 121.16 mg/100g for the raw, boiled and roasted samples, respectively. The roasted sample had the lowest value while the raw sample had the highest value. Boiling and roasting also resulted in a significant reduction in the phytate content of the samples. This result agrees with that reported by Mazahib *et al.* [32] that boiling reduced the level of phytate. According to El Maki *et al.* [33], the difference in the loss of phytic acid during boiling could probably be explained on the basis that phytate activity at a temperature of 40-55^{o}C may degrade inositol hexaphosphate to the pentaphosphate or lower molecular weight forms. It was also reported that phytic acid content decreased during boiling because insoluble complexes between phytate and other compounds were formed and accordingly the amount of free phytate will be reduced [32]. The results obtained also agreed with those of Olanipekun *et al*. [34] who reported that the phytic acid content in kidney bean decreased after roasting and boiling by 44.67% and 20.77%, respectively. Phytic acids are found in abundance in fiber-rich foods and are recommended because they protect human from cardiac vascular diseases and some form of cancer [35, 36]. With this advantage, yet phytic acid reduce the bioavailability of minerals because of its strong binding affinity to them. They chelate metal ions such as calcium, copper, iron, zinc, magnesium and molybdenum forming insoluble complexes that are poorly absorbed from gastrointestinal tract [37, 38].

Conclusion and Recommendation

This study demonstrated that boiling and roasting treatments caused changes in the nutrient, and anti-nutrient composition of African elemi. Processing methods reduced the moisture content, ash, fat, crude protein, and crude fibre contents while an increase in the carbohydrate content was observed. The roasted and boiled African elemi exhibited similar ash, crude protein and crude fibre content while the changes in the fat content was higher in the boiled sample.

Processing methods also significantly improved the calcium, potassium, and zinc content while magnesium decreased. The boiled African elemi exhibited higher potassium content while the roasted sample had higher zinc content. The boiled and roasted samples exhibited similar calcium, iron and magnesium contents. Processing on the other hand resulted in a reduction in the phytate, tannins and oxalate content of the samples. These values were within the permissible limit for oxalate, tannin and phytate in foods.

This study recommends roasting and boiling as suitable methods for the processing of African elemi with better mineral constituents and reduced anti-nutrients. Further studies should be focused on investigating the amino acid profile, mineral bioavailability and protein digestibility of the processed African elemi fruits.

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