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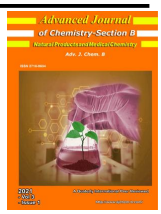

Original Research Article

Effects of processing on the nutritive and anti-nutritive properties of *Afzelia africana*

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ABSTRACT

*Afzerlia africana*seeds an edible food source were purchased and processed into different forms (frying, boiling and roasted), thereafter, subjected to chemical assessment (proximate, mineral, vitamin and anti-nutritional properties) and physiochemical properties of seed oil. Samples were analysed by official methods of analysis as results generated were subjected to one-way analysis of variance (ANOVA). The proximate compositions showed no significant difference at (P< 0.05) in the nutrients evaluated. In terms of moisture content, fried, boiled and roasted *Afzelia africana* have the values 11.13 ± 0.23%, 12.73 ± 0.23% and 12.93 ± 0.12% respectively. The protein content of all the samples was low and there was no significant difference (P< 0.05) observed. In terms of fat content, all the processed samples had higher values (14.63 16.40%) and no significant difference (P<0.05) was observed. The seed oil extracted with n-hexane at (40 60°C) shows that the acid value, saponification value, iodine value, free fatty acid and percentage oil yield showed no significant difference (P< 0.05). The processed seed samples were found to contain no less than 0.60 mg/100g of oxalate, 0.70 mg/kg of phytate. They were relatively high in cyanogenic glycosides, alkaloid, terpenoid, cyanide and flavonoid. The investigation showed a higher value of cyanide was observed in both samples ranging from 23.20 ± 1.68 µg/100g to 56.92 ± 1.66 µg/100g. The dominant mineral was sodium in all the processed form followed by calcium, while significantly low in potassium.There was no significant difference (P < 0.05) observed in the vitamin content. The various parameters investigated revealed the potential of *Afzelia africana* as a seed could serve as a source of health benefit when used as supplement in food formulation and contains active metabolites that have both medicinal and therapeutic value. In addition*Afzelia africana* can be used for production of paints, vanishes and cosmetic products such as soap and shampoo.

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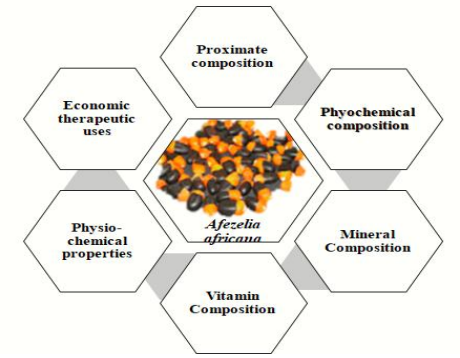
GRAPHICAL ABSTRACT



INTRODUCTION

Leguminous plants are more and more been used as possible solution to low protein diet in highly inhabited region of the world [1]. This is becausemost developed and less developed countries do not produce equitable amount to feed its populace, thereby increasing the prices of food from importation leading to high rate of food scarcity and malnutrition. Some of these countries have inadequate food supply particularly protein and they rely on carbohydrates for their daily requirements, which causes obesity, diabetes and hypertension [2].

Africa has diverse source of seed bearing tree plants, but the seeds and the seed oils are completely underutilised.*Afzelia africana, Mucuna flagellipes, Brachystegia nigerica* and *Detarium microcarpum* are great source of leguminous plants found in semi-arid, sub-Saharan and tropical zones of Africa [3]. *Afzelia africana* also known asCounter wood tree or African Oak or Mahogany bean is leguminous plant in the family of fabaceae sub family Caesalpinaceae. This deciduous plant has pods containing about 6 12 elliptical, long shaped glossy black seeds with cap like waxy orange aril, which is released by explosive mechanism, if not harvested [4, 5].

Afzelia africana contain 18 37% of oil and it is composed of palmitic and oleic acid, which required little purification and has a long shelf life. It is suitable for the production of alkyl resins and shoe polish. It is a good source of dietary protein and mineral that compare with animal protein from meat, egg and fish [6]. The nature and composition of *Afzelia africana*as a good source of nutrition calls for investigation to ascertain why rural dwellers who consume this seed plants do not record associated diseases such as obesity, cardiovascular diseases, diabetes, compromised immune system and so on [7]. Several phytochemical assessment has been conducted on *Afzelia africana* by Olorunmaiye *et al.* [8], Ogunlade *et al.* [9], which gives promising nutritive properties after dietary intake and treat health illness, as it Ayanwale *et al.* [10] feed roasted *Afzelia africana* seed to chicken birds for 9 weeks, as they grew exponentially due to its high nutrient content. Therefore, this study is aimed at evaluating the effects of processing (frying, cooking and roasting) on the proximate composition, phytochemical, vitamins, minerals and physicochemical properties of *Afzelia africana* seeds and oil in order to provide necessary information for the comprehensive utilization and also reduce postharvest losses.

EXPERIMENTAL

Source of Materials

Afzelia africana seeds were purchased from an open market in Eke Okigwe, Imo State Nigeria. The Head of Department of Plant Science and Biotechnology Abia State University, Uturu, Nigeria identified the spherical seeds. The seeds were screened to remove the bad ones and particles.

Preparation of Samples.

The seeds were cracked-open to remove the cover as shown in Figure 1. Each seed samples were divided into three equal portion, one was boiled, fried and the other roasted. 1.5kg of the raw seeds were roasted on a hot cast iron pan at a temperature of 45–55□, and continuously stirred until characterised brownish colour was obtained which indicated complete roasting. The roasted seeds were cool in a desiccator and kept for further analysis. 1.5kg of raw cracked seeds were boiled for 45 minutes in distilled water at 100□. The boiled seeds were drained using a perforated basket, thereafter dried in an oven at 50□ until well dried and kept for further analysis. 1.5kg of the raw seeds was fried on a hot cast iron pan with sand at a temperature of 45–55□. The seeds were continuously stirred until a characteristic brownish colour was obtained, which indicated complete frying, the seeds cooled in a desiccator and kept for further analysis. After all processing treatments were completed, the seed samples were sun dried to reduce moisture content and then grounded using a mechanical grinder, put in an airtight container and stored for further analysis. The chemicals and equipment/facilities used for the generation of samples and their analyses were obtained from the Department of Biochemistry, University of Nigeria, Nsukka, Nigeria.

Figure 1: The seeds of *Afzelia africana*

Proximate Analysis

Standard methodology was employed for the proximate analysis. Crude fat were extracted by the soxhlet extraction method with N hexane at 40-60□ for 8 hours as described by AOAC [11]. Crude protein content was determined by the micro kjeldahl method. Available carbohydrate, crude fibre, ash and moisture contents were estimated as described by the Association of official analytical chemists [12].

Determination of Anti-nutrients

Tannin, flavonoid and cyanide were quantified according to Trease and Evans [12] method. Alkaloid and saponin content were determined using the methods reported by Day and Underwood [13]; while oxalate was determined using the method reported by Ceiwyn [14].

Determination of Mineral Content

5g of oven dried powdered sample was weighed into dry crucibles in triplicates and ignited in a muffle furnace at 600□ until greyish white ash was obtained. The ash was cooled in a desiccators and 5cm^3 of 1.0 moldm^{-3} nitric acid was added and evaporated to dryness on a steam bath. The treated sample was heated in a muffle furnace until greyish ash was obtained. The sample removed, cooled in a desiccator and retreated by addition of 10 cm^3 of 1.0mol/dm^3 hydrochloric acid before filtering into 100 cm^3 volumetric flasks. Sodium and potassium ions were determined using the standard flame emission photometer while concentrations of the other metals were determined using Atomic Absorption Spectrophotometer (AAS Model SP9)

operating with standard air-acetylene flame [12]. Concentration of phosphorus was determined using Jenway 6100 spectrophotometer at 420 nm [15, 16].

Physicochemical Analysis of the Seed Oil

The percentage free fatty acid, iodine value, saponification number, peroxide and acid values were determined by standard method of AOAC [11].

Statistical Analysis

Results were expressed as mean ± SD (standard deviation) of three determinations. Statistical analysis was performed by One way analysis of variance (ANOVA) using statistical packaging for social science (SPSS), version 20.0 software to test significance level at ($P < 0.05$). Duncan multiple range test (DMRT) was used to separate the mean where significant differences existed. A p-value of < 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Proximate composition

The result of proximate composition of *Afzelia africana* flour showed there was no significant difference ($P < 0.05$) between the three different processing methods as shown in **Table 1**.

Table 1: Proximate Composition of *Afzelia africana*

Parameters	Fried	Boiled	Roasted
Moisture content	11.13±0.23[a]	12.73±0.23[a]	12.93±0.12[a]
Crude fat	14.63±0.58[a]	16.40±0.53[a]	14.33±0.23[a]
Crude fibre	6.73±0.31[a]	5.33±0.23[a]	6.40±0.20[a]
Ash	3.67±0.12[a]	2.53±0.12[a]	3.27±0.12[a]
Protein	3.04±1.27[a]	3.07±0.61[a]	3.11±1.22[a]
Carbohydrate	60.86±0.74[a]	59.93±0.74[a]	59.79±1.72[a]

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($P < 0.05$).

The protein content of the processed *Afzelia Africana* samples were generally low and showed no significant difference ($P<0.05$). The protein content of the samples fried, boiled and the Roasted were 3.04±1.27%, 3.07±0.61 % and 3.11±1.22% respectively. The roasted sample had high protein content while the lowest recorded for fried sample, which was low compared to results of Igwenyi and Akubugwo [17], but similar to Uhegbu *et al.* [18] as excessive heat of processing causes severe amino acid degradation by complete decomposition or by racemization and the formation of cross-linkages forming poly-amino acids [19]. Dietary proteins are needed for the formation of new cells, enzymes, hormones, antibodies and other substances required for the healthy functioning and development of the human body as well as its protection [20]. The fat content of fried, boiled and roasted *Afzelia africana* were 14.63±0.58%, 16.40± 0.53% and 14.33 ±0.23% respectively. There was no significant difference ($P < 0.05$) observed between the fat contents under the different processing methods. These values were higher than the result of Okaka *et al.* [21] on *Afzelia africana* but comparable to 14.0 18.5% reported by Del-Rio *et al.* [22] on the same seed. These variations in the oil contents is due to climatic factors, soil properties, rainfall, freshness and storage conditions/time of the seeds. Dietary fat provides energy, polyunsaturated fatty acid and fats soluble vitamins in humans. Fiber assist during bowel actions and guard against colon and rectal cancer as well as in diabetes. The percentage crude fiber content of the samples, fried boiled, and roasted were 6.73±0.31,

5.33±0.23 and 6.04±0.20 respectively. No significant difference exists between the processed samples. No Significant difference ($P < 0.05$) was observed for moisture content. The low moisture contents in the processed samples tend to have extended shelf life. This is in agreement with study by Ogungbenle [23], who stored processed *Afzelia africana*for one month as it increases ready availability and convenience in this food usage.Dietary carbohydrate is primary source of energy to the body; it spares fats and proteins in the body. The percentage carbohydrate content showed no significant differences ($P < 0.05$). These values were lower than the report of Uhegbu *et al.* [18] on similar seeds. The decrease could be because of the processing method in the preparation of the seed samples and other environmental factors [19]. This shows that consumption of any prepared form of *Afzelia africana* seeds could be useful mineral source for body growth and development.

Phytochemical composition

Table 2 shows the effects of different processing methods on the phytochemical composition of *Afzelia africana* flour. The results showed that only Flavonoid, Alkaloid and Cyanide showed a significant difference ($P < 0.05$). The phytochemical properties reveal the presence of tannin, alkaloid, cyanide, saponin, flavonoid, terpenoid and phytate.

Table 2. Phytochemical compositions of *Afzelia africana* as affected by boiling, roasting and frying.

Parameter (µg/100g)	Fried	Boiled	Roasted
Tannin	5.38±0.58[a]	2.99±1.70[a]	6.45±5.59[a]
Alkaloid	519.44±187.15[a]	849.45±34.25[b]	469.45±94.29[a]
Cyanide	50.35±2.54[a]	23.20±1.68[b]	56.92±1.66[a]
Saponin	1.22±0.12[a]	1.19±0.10[a]	1.25±0.11[a]
Flavonoid	96.69±41.39[a]	221.40±17.86[b]	150.20±146.45[b]
Terpenoid	169.82±9.70[a]	175.98±17.83[a]	148.88±51.75[a]
Phytate	3.83±0.73[a]	2.12±0.10[a]	2.69±0.05[a]
Oxalate	0.02±0.01[a]	0.01±0.01[a]	0.01±0.01[a]

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($P < 0.05$).

Afzelia africana is not devoid of anti nutritional factors. According to Okaka *et al.* [21], legumes have high nutrient contents and havepresence of several anti nutrients, which makes them useful for dietary and curative impact after consumption [16]. The concentrations of tannins were relatively low, with the values of 5.38±0.58µg/100g, 2.99±1.70µg/100g and 6.28±5.59ug/100g for fried, boiled and roasted *Afzelia africana*seeds respectively. Tannins are water-soluble polyphenolic compounds with high molecular weight as several assessment by Ujwala *et al.* [24], Latha *et al.,* [25] reported similar results, which had anti-microbial, anticancer, anti-inflammatory and antioxidant properties. Alkaloids were present in high proportion for fried, boiled and roasted *Afzelia africana* seeds, which has anti-malarial, analgesic and anti-microbial properties [26] as Wadood *et al.* [27] suggest it can cure headache, pain as well as microbial infections.The level of cyanide and cyanogenic glycosides were generally high in fried and roasted samples. The concentrations of cyanide were 50.35±2.54µg/100g, 23.20±168µg/100g, and 56.92±1.66µg/100g in fried, boiled and roasted *Afzelia africana* seed flour respectively, which showed a significant difference ($P < 0.05$). This were higher than the

values reported from the same seed (3.50 and 9.80 mg/100g) respectively by Del-Rio [22], which is considered harmful and poisonous in extreme concentration [28]. The concentrations of saponins and oxalate were generally lower than1.1mg/100g in all the different processing methods. Saponins are widely distributed in plants are used in treatment of cardiovascular diseases [23], as Friday *et al.* [26] reported that saponin possess anti-inflammatory, hepatoprotective and haemolytic properties. In decreasing flavonoid concentration, boiled *Afzelia africana* seeds> roasted*Afzelia africana* seeds> fried*Afzelia africana* seeds, which has anti-bacterial, anti-oxidant and anti-inflammatory properties [26,29,30] as it reduced hypertension and other cardiovascular diseases [30]. Terpenoids were relatively high in concentration as they are associated with saponins that stimulates enzymatic production and reduce risk of breast cancer in women. Phytate level were higher than Ejikeme *et al.* [28] as phytate interferes with biochemical digestion due to mineralization as it forms metal complexes, which is not readily adsorbed by intestinal tissues [31]. Oxalate concentration was lower than phytate, as theyimpacts on mineralization potential as it combines with calcium, magnesium and zinc compounds thatcauses kidney stones [9]. The oxalate values were lower than Ogunlade *et al.* [9] who reported 0.86mg/g and Bello *et al.* [32] who reported 0.23 to 1.10g/100g, thus no significant health issues is associated with consumption of *Afzelia africana* seeds. Considering the observed anti-nutritional factors in the seeds of the studied plant, it is indicative that they are moderately rich in anti-nutrients.

Mineral Composition

Table 3 shows the mineral composition of the different processing methods of *Afzelia africana* flour. Although, the minerals were nutritive and quantitatively low in most of the minerals, which include, potassium (0.21 ± 0.32), (0.21 ± 0.19) and (0.27 ± 0.16), phosphorous (3.83 ± 0.73), (2.12 ±0.10) and 2.69± 0.05) for fried, boiled and roasted *Afzelia africana* flour respectively. The result showed that only calcium showed a significant difference ($P < 0.05$) across the different processing methods.

Table 3. Mineral compositions of *Afzelia africana* as affected by boiling, roasting and frying

Parameters	Fried	Boiled	Roasted
Calcium (mg/100ml)	14.78±11.61 [a]	4.04±2.86 [b]	7.47±6.66 [a]
Iron (mg/100ml)	5.17±4.28 [a]	3.91±0.26 [a]	3.38±0.83 [a]
Phosphorus (µg/100ml)	3.83±0.73 [a]	2.12±0.10 [a]	2.69±0.05 [a]
Potassium (µg/100ml)	0.21±0.32 [a]	0.21±0.19 [a]	0.27±0.16 [a]
Sodium (µg/100ml)	122.27±7.62 [a]	123.43±4.26 [a]	115.53±4.52 [a]
Magnesium (µg/100ml)	11.24±3.96 [a]	10.45±0.32 [a]	11.85±3.48 [a]

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($P < 0.05$).

Minerals are essential in human nutrition as plant source has less mineral content compared to animal sources [33]. The values of iron were 5.17±4.28 mg/100ml, 3.91±0.26 mg/100ml and 3.38±0.83 mg/100ml for fried, boiled and roasted *Afzelia africana.* No significant difference ($P <0.05$) was observed. Iron is highly required for blood formation. The Sodium content of the processed seed samples were 122.27±7.62 µg/100ml, 123.43±4.26µg/100ml and 115.53±4.52 µg/100ml, for fried, boiled and roasted *Afzelia africana*. No significant difference was observed, as values reported by [34] were above. Sodium acts as neutralizing agents for

acid, also acts in nervous for organ functioning and muscle actions as well as the proper functioning of the liver, pancreas, and gall bladder. Thus, from **Table 3**, we can postulate that the amount of these mineral elements consumed on daily basis are within the required daily intake of minerals.

Vitamin Composition

Table 4 shows the effects of the different processing methods on the Vitamin composition of *Afzelia africana* flour. The results obtained showed no significant difference ($p < 0.05$) in the processing methods on the Vitamin composition.

Table 4: Vitamin compositions of *Afzelia africana* as affected by boiling, roasting and frying

Parameter (mg/100ml)	Fried	Boiled	Roasted
Vitamin A.	9.13±0.58[a]	2.99±0.38[a]	10.05±4.03[a]
Vitamin B1	1.02±1.01[a]	3.41±1.16[a]	2.80±2.73[a]
Vitamin B2	310.99±59.22[a]	345.58±56.07[a]	346.30±5.19[a]
Vitamin C	38.67±2.76[a]	29.73±9.00[a]	28.86±4.54[a]
Vitamin D	21.34±19.83[a]	5.36±3.03[a]	6.07±0.51[a]
Vitamin E	6.35±0.22[a]	0.19±0.14[a]	7.46±7.30[a]
Vitamin K	8.14±0.37[a]	3.93±0.67[a]	5.46±0.64[a]

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different ($p < 0.05$).

Afzelia africana seeds processed by different methods have a good yield of vitamin content, with vitamin B2 and C were highest in all the processed samples. There was no significant difference ($P < 0.05$) observed, as values are agreement with [35]. It is important to note that vitamin C (in the form of ascorbic acid) is a water-soluble antioxidant that stimulates the absorption of soluble iron by chelating or reduction process [36]. It has ability for scavenging free radicals and regenerate other antioxidants such as tocopheroxyl from their radical species [37]. Vitamin C content was not significant. Ascorbic acid is necessary for healthy teeth, gums and bones and is essential for proper functioning of adrenal and thyroid glands. Vitamin E content of the processed seed samples were 4.23±3.67 mg/100ml, 0.12±0.14 mg/100ml and 4.97±6.72 mg/100ml for fried, boiled and roasted *Afzelia africana* respectively. No significance difference ($P < 0.05$) was observed. The values of vitamin were found to be comparable to the values of 8.44±0.33 of tiger nut [38]. Vitamin E protects the body tissue from damage caused by substance called free radicals, which can harm cells, tissues and organs [35].

Physicochemical properties

Table 5 shows the effects of the different processing methods on the physicochemical characteristics of oil extracted from *Afzelia africana* seed. The result showed that boiled *Afzelia africana* seed has the highest percentage oil yield of 16.40±0.53% followed by fried and roasted samples with the values 14.63±0.58% and 14.33±0.53% respectively as it was not significant. The values were however higher than the oil yield of seeds used in soup thickening [18] and oil yields of *Raphia vinifera* mesocarp (seed pulp) oil [39]. The oil content was also found to be lower than castor seed 50%, cottonseed 30%, linseed 40% and palm kernel 50% [40]. A significant difference ($P < 0.05$) was observed in peroxide value and saponification value.

Table 5. Physicochemical properties of *Afzelia africana* seed oil as affected by boiling, roasting and frying

Parameters	Fried	Boiled	Roasted
Percentage Oil Yield (%)	14.63±0.58[a]	16.40±0.53[a]	14.33±0.23[a]
Acid value (mgKOH/g)	1.22±0.02[a]	2.40±0.02[a]	0.89±0.02[a]
Free Fatty Acid (%)	0.60±0.00a	1.17±0.06[a]	0.43±0.04[a]
Iodine value (Wiji s)	213.36±0.61[a]	209.35±0.04[a]	224.28±1.16[a]
Peroxide value (meq/g)	89.50±0.64[a]	107.97±1.23[a]	179.28±0.57[b]
Saponification value (mgKOH/g)	527.78±4.93[a]	524.45±1.00[a]	608.32±1.03[b]

*Values are Means ± standard deviations of triplicate determinations. Values in the same row having the same superscript letters are not significantly different (P < 0.05).

The acid values of all the samples were generally lower than the stipulated permitted maximum values of 10 mg KOH/g and 4 mg KOH/g oil for virgin palm and coconut oils, respectively [40]. No significant differences (P< 0.05) were observed. Acid value gives an indication of the quality of fatty acids in oil as it impacts the saturation index [35]. Low acid value in oil shows that the oil can remain unchanage or rancid for a long period of time. This oils can be useful in manufacturing of paints, soap and shampoos [41, 42].All processed *Afzelia africana* seed oil had a high saponification value of 527.78±4.93 mgKOH/g, 524.45±1.00 mgKOH/g and 608.32±1.03 mgKOH/g for fried, boiled and roasted respectively, Significant difference (P< 0.05) were observed between the processed seed oil samples. Saponification value is an clue to the molecular weight of oil. Oils with high saponification values are appropriate in soap making industry [42]. Saponification value is a degree of oxidation during storingof oils. Therefore, low saponification value is an indices that oil has high fatty acid that is non-edible or usable oils, as unsaturated fatty acid acts as a protective role againts cardiovascular disease [28]. The iodine values were generally high, no significant difference (p< 0.05) exist between the processed samples. The iodine values were 213.36±0.61, 209.35±0.04 and 224.28 ±1.16 Wij s for fried, boiled and roasted *Afzelia africana* seed oil respectively. The iodine (Wij s) value of the processed samples were higher than prescribed 75 94 Wij s value for vegetable oils [43]. Iodine value measures the unsaturation of oil and is a useful criterion for purity and identification as it can be used to in surface coating industries in modified alkyd resin production. Thus, the value obtained for these processed seed oil classify it as semi-drying oil, as such the seed oil will be suitable as alky resins for formulations of paint or varnishes [44].

Conclusion

Afzelia africana seeds have high and rich source of carbohydrate, fatty acid and protein contents. The moisture level of the seeds was low resulting in low acid value, free fatty acids and high saponification as well as the moderately high iodine values of the oil samples suggests that it could help hyperlipidaemia patients. The oil is semidrying because of its moderately high iodine value and thus useful in the manufacturing of surface coating agents. The low level of anti-nutrients makes the processed flour from *Afzelia africana* seeds nutritionally useful. With a few exceptions, the results of the experiments presented here show that the exposure of *Afzelia africana* seeds prior to oil extraction to different preparation methods (frying, boiling, and roasting) caused no significant loss or change in the content of proximate, mineral, vitamin, anti-nutrients and physicochemical properties.

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Conflict of interest

The authors declare that there is no conflict of interests whatsoever regarding this manuscript.

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