JOURNAL OF CURRENT RESEARCH IN FOOD SCIENCE

E-ISSN: 2709-9385
P-ISSN: 2709-9377
JCRFS 2022; 3(2): 98-103

www.foodresearchjournal.com
Received: 24-05-2022
Accepted: 28-06-2022

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Evaluation of the effects of thermal processing treatments on the nutrient and anti-nutrient composition of *Afzelia africana* (Akparata) flour

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Abstract
This research work aimed to evaluate the effects of thermal processing treatments on the nutrient anti-nutrient composition of *Afzelia africana* (*Akparata*) flour. The seeds were sorted, cleaned and processed into boiled, roasted and autoclaved lima bean flours. The flours obtained were analysed for proximate, vitamin and anti-nutrient contents using standard methods. The proximate composition of the samples revealed that the flours had a range of moisture, 8.23-12.40%, crude protein, 15.98-25.95%, fat, 21.00-28.21%, ash, 1.34-2.89%, crude fibre, 2.00-3.45%, carbohydrate, 38.68-49.33%, and energy 424.13 – 482.37 kJ/100g, respectively. The vitamin contents of the flours showed that the samples contained 0.02±0.00 - 0.08±0.00 mg/100g riboflavin, 0.78 - 1.98 mg/100g niacin, 0.40 - 0.89 mg/100g thiamine, 120.40-234.70 mg/100g vitamin A, 72.11-134.19 mg/100g ascorbic acid, 09.67-17.65 mg/100g vitamin E, 310.60-430.60 mg/100g B_6, 3.47-5.87 mg/100g B_{12}, respectively.
The result of the anti-nutrient composition of the flours also showed that the phytate, tannin, oxalate, cyanogenic glycosides, protease inhibitors, haemagglutinins inhibitors, levels of the samples were significantly ($p \leq 0.05$) reduced by roasting and boiling treatments compared to the sample processed by autoclaving. In addition, the saponin content of the flours was relatively higher in boiled sample than in roasted and autoclaved flours. However, the nutrient and anti-nutrient contents of the flours observed that the flours have the potentials to be used as nutritional supplements in the preparation of a variety of food products than the raw sample.

Keywords: *Afzelia africana*, boiling, roasting, autoclaving, proximate, vitamin, anti-nutrient content

Introduction
Background of Study
Afzelia africana is one of the underutilized legumes which can be used as a plant protein substitute for the expensive animal protein (Odenigbo and Obizoba *et al*., 2014) [10]. Onweluzo *et al*. (1995) [18] reported that the seed contains about 32% protein, which is significantly high and comparable to other legumes. *Afzelia africana* grows widely in farmlands and forests in Nigeria. *Afzelia africana* is called *Detarium microcarpum* or Counter wood tree or African Oak or Mahogany or "*Ofo*" in South-eastern Nigeria. It 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. It is commonly known as "*Ofo*" in South-eastern Nigeria. It survives the harshest weather conditions such as harmatan and effects of some global climate change. Fruits and vegetables are major sources of micronutrients. It is imperative to make serious efforts to identify, process and popularize other locally available and cheap, nutritious seeds and their dishes to meet the protein and micronutrient needs of the nation – Nigeria. It is of necessity to lay much more emphasis on nutrition education, and bring to the limelight the importance of legumes especially the lesser known ones to the nutrition of diets of both children and adults (Odenigbo and Obizoba *et al*., 2014) [10]. Traditionally, legumes and vegetables are added to foods to improve the "eye-catching" appeal rather than for the nutrients and phytochemicals they contain. During dry season in Nigeria, yam is consumed with raw palm oil, yam porridge without any legumes or vegetables, plain sauces thickened with cocoyam or rice without legumes or vegetables. *Afzelia africana* has many tender and succulent leaves and young shoots readily available in the forests and farmlands during the dry season. The processing methods adopted by the indigenes and the nutrition implication of the use of seed *Afzelia africana* as vegetable has not been adequately investigated and reported in literature.

In addition to their protein contributions, legumes are also rich in other nutrients such as starch, dietary fibre, protective phytochemicals, oil, vitamin and mineral elements (Onweluzo *et al*., 1995) [18].

Phytochemical screening determines the presence of biologically active non-nutritive compounds that contribute to the flavor, colour and other characteristics of plant parts. These compounds such as alkaloids, tannins, cardiac glycosides, terpenoids, saponins, anthraquinones, flavonoids, and so on, are the major basis of pharmacological activities of medicinal plants (Ayanwale *et al*., 2007) [2]. In recent years, the global demand for alkaloids and their derivatives as well as other bioactive compounds has grown substantially (Ayanwale *et al*., 2007) [2]. The presence of many secondary metabolites in plants and plant products have been shown to display potent antimicrobial activity against organisms and potency in treating diseases (Onweluzo *et al*., 1995) [18].

In order to reduce protein- energy malnutrition and enhance product diversification of underutilized legumes, the exploitation of *Afzelia africana* (*Akparata*) requires greater research attention. *Afzelia africana* which is popular in the eastern part of Nigeria, is a woody plant mostly found in the rain forest zone. The seed is seasonal but its use in soup making is all year round. The seed can be processed in large quantities into flour and preserved to eliminate the inconvenience encountered by the home – maker (Okaka, 2005) [11]. When this is achieved it will reduce the seasonal glut of the product and occasional scarcity experienced each year. In order to further widen the frontiers of the nutritional status of *Afzelia africana*, this study is undertaken to address the effects of different heat treatments on nutrients, antinutrients, amino acid profile, functional properties and biochemical indices of aqueous extract of *Afzelia africana* seed flour. This study will contribute to the data bank for the effective utilization of *Afzelia africana* seed for the development of composite blend in food industries as valuable products. The main objective of this research is to determine the effect of different thermal processing treatments on the nutrient and antinutrient composition, amino acid profile, functional properties and biochemical indices of aqueous extracts of *Afzelia africana* (*Akparata*) flours.

Materials and Method

The sample used for the study was collected from Obed's Agro-farm in Amodu Awk in Nkanu West Local Government Area, Enugu State, Nigeria and the reagents used for this analysis were purchased from Conraw Scientific Company Independence Layout Enugu, Enugu State. The seeds were sorted, cleaned and divided into four equal portions of 500g each. Three portions were subjected to different processing treatments (boiling, roasting and autoclaving) while the fourth batch was processed raw.

Sample Preparation

Preparation of Raw *Afzelia africana* (*Akparata*) Flour

The raw *Afzelia africana* (*Akparata*) was prepared according to the method of Ugwu and Oranye (2006) [17] with slight modifications. During preparation, five hundred grams (500g) of *Afzelia africana* (*Akparata*) seeds which were free from dirt and other extraneous materials were weighed and cleaned. The cleaned seeds were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60 ^{0}C for 3 h with occasional stirring of the seeds at intervals of 30min to ensure uniform drying. The dried seeds were cracked, winnowed and milled into flour using the locally fabricated attrition mill and sieved through a 435 micron mesh sieve. The flour produced was packaged in an airtight plastic container and kept in a freezer until needed for analysis.

Preparation of Boiled *Afzelia africana* (*Akparata*)

The boiled *Afzelia africana* (*Akparata*) was prepared according to the method of Ugwu and Oranye (2006) [17] with slight modifications. During preparation, five hundred grams (500g) of *Afzelia africana* (*Akparata*) seeds which were free from dirt and other extraneous materials were weighed and cleaned. The cleaned seeds were boiled for 30, 45, 60 at temperature 95 ^{O}C to enable the dehulling operation. The dehulled seed were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60 ^{0}C for 3 h with occasional stirring of the seeds at intervals of 30min to ensure uniform drying. The dried seeds were cracked, winnowed and milled into flour using the locally fabricated attrition mill and sieved through a 435 micron mesh sieve. The flour obtained were packaged, labeled and stored in an air tight container at room temperature (25 ^{O}C) (28±2 ^{O}C) until required for analysis.

Preparation of Roasted *Afzelia africana* "*Akparata*" Flour

The roasted *Afzelia africana* "*Akparata*" flour was prepared according to the method of Ugwu and Oranye (2006) [17] with slight modifications. During preparation, five hundred grams (500 g) of *Afzelia africana* "*Akparata*" seeds that was free from dirt and other extraneous materials was weighed and cleaned. The cleaned seeds was spread on the trays and roasted in a hot air oven (Model DHG 9101 ISA) at 240 ^{0}C for 30, 45 and 60 min (respectively) with occasional stirring of the seeds at intervals of 5 min to ensure uniform roasting. The roasted seeds were cracked, winnowed and milled in the attrition mill and sieved through a 435 micron mesh sieve. The flour produced was packaged in an airtight plastic container and kept in a freezer until needed for analysis.

Preparation of Autoclaved *Afzelia africana* "*Akparata*" Flour

The autoclaved *Afzelia africana* flour was prepared according to the method of Ugwu and Oranye (2006) [17] with slight modifications. Half kilogram (0.5k g) of Pigeon pea seeds which was free from dirt and other extraneous materials was weighed, cleaned and soaked in 2 litres of potable water at room temperature (30±2 ^{O}C) for 12 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing them in between palms to remove the hulls. The dehulled seeds were placed in a beaker and autoclaved in an autoclave (Model 75xG) at temperature of 121 ^{O}C and pressure of 6 atmospheres for 40 min. The autoclaved seeds were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60 ^{O}C for 4 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using the attrition mill and sieved through a 500-micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a freezer until needed for analysis.

Chemical Analysis

The moisture, crude protein, fat ash and crude fibre contents of the samples were determined in triplicate according to the method of AOAC (2006). Carbohydrate was determined by difference *(*Anton *et al*., 2008*)*. The energy content of the flours was calculated from the proximate composition using the Atwater factor 4×protein, 9×fat, 4×carbohydrate *(Shumaila and Mahpara,2009).* The ascorbic acid and niacin contents of the samples were determined according to the method of AOAC (2006). The thiamine and riboflavin contents of the flours were determined according to the flourimetric method of Onwuka (2005). Vitamin A and Vitamin E were determined by the method of Ene-Obong and Obizoba (1996) [5]. The alkaloid, tannin, saponin, oxalate and trypsin inhibitor levels of the samples were determined using the spectrophotometric method of Onwuka (2005). Phytate was determined by the solvent extraction gravimetric method of AOAC (2006).

Statistical Analysis

The data generated after the analysis were subjected to Analysis of Variance (ANOVA) using special package for social sciences (SPSS version 20, 2013) to detect significant differences among the sample means at ($p \leq 0.05$). Significant means were separated using Turkey's Least Significance Difference (LSD) test.

Results and Discussion

Proximate Composition

The proximate composition of the samples is presented in Table 1. The moisture content of the sample was significantly ($p \leq 0.05$) higher in boiled sample compared to the samples processed by autoclaving and roasting. The increase could be attributed to the inhibition of large quantity of water by the seeds as a result of boiling during processing. The observation is in agreement with the report of Nsa and Ukachukwu (2009) [8]. The high moisture affects the storage stability of legume and other flour products. The crude protein content of the flour was significantly ($p \leq 0.05$) lower in boiled and autoclaved samples than in roasted flour sample. The reduction in the protein content of the boiled flour could be attributed to leaching of some soluble protein into the boiling water during processing (Obasi and Wogu, 2008) [9]. Dietary proteins are needed for the synthesis of new cells enzymes and hormones required for the development of the body (Okaka *et al.,* 2006) [11]. The ash content of the raw sample was found to be significantly ($p \leq 0.05$) reduced by autoclaving treatment compared to roasted and boiled samples, respectively. The high ash content by boiled and roasted flour is an indication that they are food sources of minerals than in the autoclaved sample. (Okoye and Mazi, 2012) [12]. The fat content of the flours was significantly ($p \leq 0.05$) reduced by autoclaving followed by boiling and roasting treatments. Fat is important in human diets because it is a high energy-yielding nutrient. Legumes seeds are generally low in fats and oil (Okaka *et al.,* 2006) [11]. The crude fibre content of the samples was significantly ($p \leq 0.05$) reduced by autoclaving compared to boiling and roasting treatments. Fibre has been credited for promotion of increased excretion of bile acids, sterols and fats which have been implication in the etiology of certain ailments in humans (Okaka *et al.,* 2006) [11]. The carbohydrate content of the flours was significantly ($p \leq 0.05$) lower in boiled and autoclaved flour than in the sample processed by roasting. The decrease could be attributed to thermal decomposition of some carbohydrate components into carbonic acid and carbon dioxide by boiling and roasting treatments (Obasi and Wogu, 2008) [9]. The energy content of the sample was significantly ($p \leq 0.05$) increased by autoclaving and roasting treatments compared to the sample processed by boiling. The increase in energy content of the sample could be a reflection of their high protein and carbohydrate content (Obum *et al.,* 2006). Generally boiling, roasting and autoclaving treatments greatly increased some nutrient contents of lima bean flours by reducing their antinutrient contents.

Vitamin Contents

Table 2 shows the vitamin contents of lima bean flours. The ascorbic acid content of the flours ranged from 72.11 to 134.19mg/100g with the roasted and boiled samples having the highest (134.19mg/100g) and least (72.11mg/100g) values, respectively. The differences could be due to oxidation and leaching of the vitamin into boiling water during boiling, roasting and autoclaving of the legumes. Generally, the raw sample had higher ascorbic acid content than the processed samples (boiled, roasted and autoclaved samples). Ascorbic acid plays an important role in the prevention of scurvy. It also promotes the wound healing, healthy immune system and prevents cardiovascular diseases (Okaka *et al.,* 2006) [11]. Ascorbic acid is easily destroyed by oxidation, especially at high temperatures and it is the vitamin most easily lost during food processing (Potter and Hotchkiss, 2006) [14]. Roasting improves the amount of Ascorbic acid more than boiling and autoclaving which are crucial for body performance, prevents scurvy, aid wound healing, healthy immune system and cardiovascular diseases (Lee and Kader, 2000). The thiamine content of the samples which ranged from 0.40 to 0.89mg/100g was significantly ($p \leq 0.05$) reduced by boiling and autoclaving followed by roasting treatment. Thiamine functions as a coenzyme in energy metabolism. It helps in the functioning of peripheral nerves and treatment of beriberi (Potter and Hotchkiss, 2006) [14]. The riboflavin content of the flours was significantly ($p \leq 0.05$) increased by autoclaving than the boiling and roasting treatments. The autoclaved sample recorded higher riboflavin content than the raw sample. Riboflavin functions as part of a group of enzymes called flavoproteins. Flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) assist in the respiratory chains of cellular metabolism more especially in the oxidation-reduction reaction involving the release of energy. More so, the presence of this vitamin improves growth, reproduction and prevents anaemia and abnormal gait (Potter and Hotchkiss, 2006) [14].

The niacin content of the samples varied from 0.78 to 1.98mg/100g, a range that is lower than the level of niacin (3.86 to 4.58mg/100g) reported by Okoye and Mazi (2012) [12] for boiled and roasted groundnut flours. Niacin which is equally a member of the B-complex vitamin functions as a co-enzyme (NAD and NADP) in the body. It also has specific effect on the growth and plays an important role in reducing the levels of blood cholesterol (Potter and Hotchkiss, 2006) [14].

The vitamin A content of the raw sample which was found to be 118.70mg/100g was significantly ($p \leq 0.05$) reduced by autoclaving followed by boiling and roasting treatments. Vitamin A helps in maintenance of normal vision of the

eyes (Okaka *et al.*, 2006) [11]. A deficiency of vitamin A leads to blindness, failure of normal bone and tooth development in the young children. (Potter and Hotchkiss, 2006) [14]. The Vitamin E content of the samples was significantly ($p \leq 0.05$) reduced by autoclaving than the boiling and roasting treatments. The values obtained in the study were higher than those (1.45-2.68mg/100g) reported by Ibrahim *et al.* (2002) for cooked and soaked cowpea flours. Vitamin E is a strong antioxidant which functions as such in human metabolism. It is also able to spare carotene and vitamin A from oxidative destruction. Generally, the result showed that the processed lima bean flours could be used as nutritional supplements in the formulation of a number of food products than the raw sample.

Anti-nutrient Contents

Table 3 shows the anti-nutrient contents of *Afzelia africana* flours. The phytate content of the samples which ranged from 0.08 to 1.10% was significantly ($p \leq 0.05$) lower in autoclaved and boiled flours compared to the sample processed by roasting. The decrease is an indication that autoclaving and boiling have greater reduction effect on the phytate level of the raw *Afzelia africana* than the roasting treatment. The tannin content of the raw sample which was found to be 0.65% was significantly ($p \leq 0.05$) reduced to 1.2% by autoclaving followed by boiling (0.72%) and roasting (0.06%) treatments, respectively. According to Udensi *et al.* (2003) tannin lead to hard cook phenomenon in pulses, which increased the cooking time of legume grain. The apparent decrease in tannic acid during boiling and autoclaving could be attributed to the formation of insoluble complexes between tannin and other components (Sandberg, 2002). Phytate related compounds have been reported to have beneficial effect as an antioxidant (Echendu *et al.*, 2009). The presence of tannin in food has been reported to have deleterious effect in inhibiting the absorption of certain minerals such as zinc, calcium and magnesium in humans (Oke, 1996). Tannins are known to reduce protein quality directly by forming complexes thereby decreasing its digestibility and palatability. Tannins can equally participate in oxidation-reduction reactions which results in the loss of ascorbic acid (Nget-Hong *et al.*, 1983) [7]. Reduction in tannin during processing will however improve the utilization of such nutrients. The oxalate content of the processed samples ranged between 0.006 -0.013mg/kg with autoclaved and roasted flours having the least and highest values, respectively. The decrease could be due to leaching of oxalate into the boiling water. Oxalates affect calcium and magnesium metabolism and react readily with proteins to form complexes which have an inhibitory effect in the peptic digestion (Akande *et al.*, 2010) [1]. The reduction in oxalate content could increase the availability of the minerals which are usually bound to the oxalates.

The cyanogenic glycoside content of the samples which ranged from 0.013 to 0.19% were significantly ($p \leq 0.05$) lower in autoclaved and boiled flours compared to the sample processed by roasting. This were lower than the values reported from the same seed (3.50 and 9.80 mg/100g) respectively by Del-Rio *et al.* (1997) [3], which were regarded as harmful and poisonous in extreme concentration (Ejikeme *et al.*, 2010) [4].

The protease inhibitor level of the samples ranged from 2 to 18.41% with roasted and autoclaved flours having the least and highest values, respectively. The observation is in agreement with the report of Obasi and Wogu (2008) [9]. Boiling for 30mns, 45min and 60min reduced protease inhibitor content of the seed by 19.20%, 46.30% and 56.00% respectively while autoclaving reduced it by 22.77%. The higher reduction of the inhibitor by boiling could be a combined effect of high temperature and time as well as aqueous medium in which the seed was boiled or that the ant – nutrient might be more volatile during wet heating than dry heating. This observation agreed with Enwere, (1998) [6] who stated that conditions of heating (time, temperature, moisture and particle size) influence the rate and extent of protease inhibitor inactivation.

The haemagglutinin content of the processed samples ranged between 12.12 to 15.27 Hui/g with the autoclaved sample having the highest value (15.27 Hui/g) while the boiled sample had the least value (12.12 Hui/g). The reduction in the haemagglutinin content observed in boiled samples could be attributed to the combined effect of high temperature and time as well as aqueous medium in which the seed was boiled or that the ant – nutrient might be more volatile during wet heating than dry heating (Uche *et al.*, 2014) [16]. The values (0.30 to 4.31Hui/g and 0.33 to 3.21 Hui/g) obtained in the study for the processed samples were generally higher than the safe levels (0.14 to 4.72 Hui/g) reported by Sangronis *et al.* (2007) [15] for haemagglutinins.

Conclusion

The findings from the present study showed that *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 and free fatty acids suggesting that it could aid in management of hyperlipidaemia. Autoclaving followed by boiling generally resulted in reduction in the protein, ash, fat, fibre, niacin and riboflavin contents of the products. The use of roasting in the treatment of *Afzelia africana* yielded product with increased carbohydrate, thiamin, ascorbic acid, vitamin A and vitamin E contents. Furthermore, of all the heat processing treatments used drastically reduced the anti-nutrient contents of *Afzelia africana* It is therefore recommended that any of the processes can be used for processing *Afzelia africana*, however, due to the fact that autoclaves are quite expensive and may not be affordable by local producers or manufacturers of *Afzelia africana* products, boiling and roasting can be easily employed.

Table 1: Proximate Composition of thermally processed *Afzelia africana* flours

Sample	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Total Ash (%)	Crude Fibre (%)	Carbohydrate Content (%)	Energy (kJ/100g)
Raw Flour at	12.40±0.01	25.95±0.07^{a}	21.00±0.03^{f}	1.88±0.40^{b}	2.40±0.00^{b}	42.37±0.00^{d}	462.28^{c}
Boiled at 95ºC 30 min.	16.23±0.11^{a}	22.12±1.23^{b}	22.12±1.50^{e}	1.96±0.12^{b}	2.00±1.27^{c}	37.57±1.90^{g}	437.84
45 min	15.12±0.23^{b}	20.87±0.12^{c}	21.23±1.25^{f}	2.00±1.27^{ab}	2.10±1.00	38.68±1.56^{f}	429.27^{f}
60 min	13.07±0.41^{c}	19.14±2.39^{d}	20.81±0.18^{f}	2.13±0.13^{a}	2.78±0.00^{b}	40.07±0.34^{de}	424.13^{g}
Roasted at 70 ºC 30min	8.23±0.12^{f}	17.00±1.34^{e}	23.29±0.29^{d}	1.70±0.34^{c}	3.45±1.90^{a}	49.33±1.34^{a}	474.93^{c}
45 min	8.21±1.45^{e}	16.98±0.67^{e}	22.58±0.34^{e}	1.98±1.10^{b}	3.01±0.12^{a}	47.24±1.34^{b}	460.10^{c}
60 min	9.78±0.20^{e}	15.98±0.23^{ef}	22.09±0.23^{e}	1.34±0.56^{d}	2.98±1.36^{ab}	45.83±1.23^{c}	446.05^{e}
Autoclaved at 75 ºC 30min.	9.79±1.20^{e}	18.78±0.17^{d}	25.56±1.12^{c}	1.76±0.29^{c}	2.20±1.78^{c}	43.91±0.67^{d}	480.80^{b}
45 min.	10.12±0.34^{de}	17.24±1.21^{e}	28.21±1.09^{a}	1.99±1.23^{b}	2.56±0.98^{b}	39.88±1.05^{e}	482.37^{a}
60 min.	11.05±1.45^{d}	16.55±0.$_{20}$^{e}	27.10±1.34^{b}	2.89±0.20^{a}	2.90±1.89^{ab}	37.51±0.23^{g}	460.14^{d}

Data are means scores of duplicate determination ±SD. Data in the same column bearing different superscripts are significantly different (p≤0.05). Values in the same row bearing different superscripts differed significantly (p≤0.05).

Table 2: Vitamin composition of thermally processed *Afzelia africana* flours

Sample	Raw	Roasted at 70ºC for			Boiling at 95ºC for			Autoclaving at 70ºC for		
		30min	45min	60min	30min	45min	60min	30min	45min	60min
Niacin	1.98±1.02^{a}	1.20±1.00^{b}	1.10±1.00^{b}	0.89±1.02^{c}	1.10±1.00^{b}	1.01±1.00^{b}	0.78±1.02^{d}	1.20±1.00^{b}	1.10±1.00^{b}	0.89±1.02^{c}
Thiamin	0.89±0.12^{a}	0.56±0.23^{b}	0.50±0.23^{b}	0.40±0.12^{c}	0.56±0.23^{b}	0.50±0.23^{b}	0.40±0.12^{c}	0.56±0.23^{b}	0.50±0.23^{b}	0.40±0.12^{c}
Vit. A	234.70±0.10^{a}	189.20±0.18^{b}	180.40±0.18^{c}	178.70±0.10^{d}	129.20±0.18^{e}	120.40±0.18^{e}	118.70±0.10^{f}	189.20±0.18^{b}	180.40±0.18^{c}	178.70±0.10^{d}
Vit. C	134.19±5.34^{a}	78.19±1.00^{g}	76.20±1.10^{h}	72.11±5.44^{i}	87.19±1.00^{d}	82.20±1.10^{e}	80.11±5.44^{f}	100.19±1.00^{b}	90.20±1.10^{c}	87.11±5.44^{d}
Vit. E	17.67±1.20^{a}	12.12±1.36^{b}	12.12±1.36^{b}	17.64±1.20^{a}	12.12±1.36^{b}	10.10±1.36^{c}	09.67±1.20^{d}	12.12±1.36^{b}	12.10±1.36^{b}	17.65±1.20^{a}
Vit. B_2	52.24±0.26^{a}	40.34±0.26^{b}	36.24±0.26^{c}	34.12±0.26^{d}	38.24±0.26^{bc}	36.45±0.26^{c}	34.10±0.26^{d}	42.24±0.26^{b}	40.24±0.26^{b}	39.12±0.26^{bc}
Vit. B_3	27.60±2.10^{a}	15.60±2.10^{f}	12.40±2.10^{g}	11.60±2.10^{g}	18.60±2.10^{d}	17.40±2.10^{e}	15.60±2.10^{f}	23.60±2.10^{b}	$_{20}$.40±2.10^{c}	18.60±2.10^{d}
Vit. B_6	430.60±4.20^{a}	330.70±4.20^{d}	320.71±4.20^{e}	310.60±4.20^{f}	340.70±4.20^{c}	330.71±4.20^{c}	$_{320}$.60±4.20^{e}	370.70±4.20^{b}	340.71±4.20^{c}	320.60±4.20^{e}
Vit. B_{12}	5.87±0.83^{a}	4.78±0.83^{b}	3.72±0.83^{d}	3.47±0.83^{d}	4.80±0.83^{b}	4.6±0.83^{c}	3.40±0.83^{d}	5.10±0.83^{b}	4.80±0.83^{b}	4.10±0.83^{cd}

Data are means scores of duplicate determination ±SD. Data in the same row bearing different superscripts are significantly different (p≤0.05). Values in the same column bearing different superscripts differed significantly (p≤0.05).

Table 3: Antinutrient composition of thermally processed *Afzelia africana* flours

Sample	Raw	Roasted at 70ºC for			Boiling at 95ºC for			Autoclaving at 75ºC for		
Anti-nutrient		30min	45min	60min	30min	45min	60min	30min	45min	60min
Phytate %	1.10±0.04^{a}	1.02±1.10^{b}	1.00±0.00^{b}	0.80±0.13^{c}	1.06±0.14^{a}	1.02±1.12^{b}	0.89±0.13^{c}	1.07±0.23^{a}	1.04±0.12^{a}	1.00±0.12^{b}
Tannin (mg/kg)	1.2 ±0.12^{a}	0.90±0.11^{c}	0.70±0.00^{d}	0.57±1.23^{e}	1.00±1.02^{b}	0.80±1.21^{c}	0.72±0.14^{d}	1.02±0.00^{b}	0.91±0.12^{c}	0.78±1.23^{d}
Oxalate %	0.013±0.00^{a}	0.010±0.10^{b}	0.008±0.21^{d}	0.006±0.12^{e}	0.011±0.15^{b}	0.009±0.23^{c}	0.006±0.10^{e}	0.012±0.30^{a}	0.010±0.12^{b}	0.009±1.01^{c}
Cyanogenic glycosides	0.19±0.02^{a}	0.016±0.12^{b}	0.014±0.16^{c}	0.010±0.12^{e}	0.15±0.13^{c}	0.014±1.11^{c}	0.011±0.12	0.17±0.19^{b}	0.016±1.11^{b}	0.013±0.11^{d}
Protease inhibitor (TU/mg)	25.25±0.20^{a}	23.01±0.21^{c}	21.10±0.12^{e}	20.12±0.01^{e}	24.01±0.23^{b}	23.17±0.12^{c}	22.12±0.13^{d}	24.23±1.00^{b}	23.89±0.12^{c}	23.09±0.00^{c}
Hemmaglutinins (Hu/mg)	15.27±0.00^{a}	14.23±1.12^{d}	12.14±1.03^{e}	12.56±0.10^{f}	15.01±0.23^{c}	14.17±0.12^{d}	12.12±0.13^{e}	15.23±1.00^{b}	14.89±0.12^{c}	14.09±0.00^{d}

Data are means scores of duplicate determination ±SD. Data in the same row bearing different superscripts are significantly different (p<0.05). Values in the same column bearing different superscripts differed significantly (p≤0.05).

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