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Proximate and Nutritional Compositions of Breadfruit (*Artocarpus Altilis*) Seeds

B.W. Tukura*, O. Obliva
Chemistry Department, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, Nigeria

Abstract: *Proximate, minerals and vitamins composition of raw, boiled-dehulled and boiled-undehulled seeds of Artocarpus altilis were determined using standard methods. The percentage ash content of the raw sample was highest (2.49 ± 0.01%), and the least (2.42 ± 0.02%) in the boiled-dehulled seeds. The moisture content ranged from 8.05 ± 0.01% for the raw to 8.19 ± 0.02% for the boiled-undehulled. The highest crude fat and crude fibre contents were recorded in the raw (7.48 ± 0.02%) and boiled-undehulled (5.38 ± 0.01%) respectively. Carbohydrate level in the raw sample (72.66 ± 0.01%) was the highest amongst parameters and samples determined. Boiling generally decreased fatty acids, crude fat and the energy contents of the food samples but increased its protein content. The Na/K ratios were low (0.03 - 0.09mg/g). Mineral contents of the raw sample were highest for sodium (0.81%) and potassium (0.94%). Boiling and dehulling decreased sodium and potassium contents. Breadfruit may serve as good source of Vitamins. Considering Recommended Dietary Association (RDA) nutritional requirements, breadfruit is a rich source of potassium, vitamin C, thiamine, calcium and pyridoxine.*

Keywords: *Processing, proximate, nutritional, Artocarpus altilis, seeds*

I. Introduction

Legumes represent a major direct source of food for man and livestock, and make a critical contribution to increased food security of subsistence farmers. A large number of legume species are cultivated worldwide as ornamentals, living fences and firebreaks. They are also cultivated as soil binders, green manures, fodder for livestock, forage for honey bees, food for humans, in agro forestry and reforestation (for nitrogen fixation), as pulp for paper production, fuel woods, timber, and as sources of chemicals, oils and medicines [1].

Soft breadfruit is best for making chips and these are being manufactured commercially in Trinidad and Barbados. The large and thick leaves are deeply cut into pinnate lobes. Some breadfruits were canned in Dominica and Trinidad for shipment to London and New York. In Jamaica, Puerto Rico and the South Pacific, fallen male flower spikes are boiled, peeled and eaten as vegetables or are candied by cooking for 2-3 hours, then rolled in powdered sugar and sun-dried. The seeds are boiled, steamed, roasted over a fire or in hot coals and eaten with salt. In West Africa, they are sometimes made into a puree. Under ripe fruits are cooked for feeding to pigs [2]. Soft-ripe fruits need not be cooked and constitute a large part of the animal feed in many breadfruit-growing areas of the Old and New World. Breadfruit has been investigated as potential material for chick feed but has been found to produce less weight gain than cassava or maize despite higher intake [3].

Breadfruit has moderate levels of essential vitamins and minerals, and low fats [4]. All parts of the tree, including the unripe fruit, are rich in milky, gummy latex. The seed is variously cooked as porridge alone or mixed with other food stuff such as sorghum, or roasted and sold with palm kernel (Elaeis guineensis) as road side snack [5]. It is prepared and eaten in all stages of maturity, it can be roasted, baked, boiled, fried, fermented, frozen and dried and ground into flour [2]. In Nigeria, the breadfruit is regarded as the poor man's substitute for yam (Dioscorea esculenta), because it is used in several traditional food preparations of yam [6]. Very ripe breadfruit becomes sweet as the starch converts to sugar. The fermentable sugar could be efficiently utilized as an adjunct in brewing methods, helping in the development of new products as well as in obtaining concentrated wurt. Some varieties are good source of antioxidants and carotenoids [7]. These multipurpose trees also provide construction materials, medicine, fabric, glue, insect repellent, animal feed, and more [8].

Breadfruit is an important component in traditional agro forestry systems and can be grown with a wide range of plants. The trees support sustainable agriculture, improve soil conditions and watersheds, and provide food security. All parts of the tree, including the unripe fruit, are rich in milky, gummy latex. There are two main types of the tree: the normal and wild bread fruit (cultivated in some areas) produce seeds and with little pulp, while the cultivated (more widely grown) are seedless, however, occasionally, a few fully developed seeds are found in seedless cultivar [2].

Breadfruit intake is believed to help people suffering from diabetes. Studies indicate that African breadfruit consumption may reduce sugar level in people. The fibre present in breadfruit reduces absorption of glucose from the consumption of the food people eat [9]. Breadfruit intake reduces harmful cholesterol or low-density lipoprotein (LDL) in the body and increases high- density lipoprotein (HDL) cholesterol that is

beneficial for health Regular consumption of breadfruit also helps lower the risk of developing colon cancer, reduce blood pressure, asthmatic symptoms and serious health implications [10]. Breadfruit is a rich source of fatty acids like omega-3 and omega-6 which are vital for the proper development of the mind and body and also contain both saturated and unsaturated fatty acids. Fatty acids also regulate metabolic functions, promote reproduction, enhance skin colour and accelerate bone health [11]. The use of legumes in local diets largely depends on its nutritional quality and cooking characteristics. Accurate knowledge of the nutrient intake of individuals and groups of people requires information on the nutrient content of cooked food. The aim of the study is to assess the effect of processing on the proximate composition and nutritional contents of bread fruits.

II. Materials and methods

2.1 Sampling and Sample Preparation

Breadfruit (Artocarpus altilis) seeds were collected during the rainy season from the parent plant located in Achi Enugu state of South-East Nigeria, in August 2013. The samples were identified at the Department of Plant Science and Biotechnology, Nasarawa state University, Keffi. Stones and other large particles were removed from the raw sample and then washed with distilled water to remove extraneous matter. It was then partitioned into three portions. The first portion was parboiled at 100 ºC for 15 minutes and dehulled. The second portion (undehulled) was also parboiled at 100 ºC for 15 minutes. The dehulled, undehulled and raw seeds were air-dried for four days in open environment and milled to powder using a blender. The blended samples were then stored in air tight plastic containers prior to analysis.

2.2 Proximate Analysis

Standard methods [12] were used to determine the moisture, crude protein, crude fat, total ash and crude fiber contents of the raw, dehulled and undehulled sample.

2.3 Mineral Content Determination

2.00g of samples was weighed and digested using concentrated nitric and hydrochloric acids in the ratio 1:3 until the samples dissolved completely and the final volume was made up to 100cm^3 with deionized water. Fe, Cu, Zn and Mn were determined using Computer Control Thermo Fisher Scientific ICE 3000 Series Atomic Absorption spectrometer (AAS), while Na^+ and K^+ were determined using Flame photometer.

2.4 Vitamins Determination

Vitamins A, B_1, B_2, B_3, B_6 and C were determined using the methods of analysis described by [13].

2.4.1 Vitamin A

Five grams (5g) of the sample was weighed and soaked in 20 cm^3 of analytical grade acetone at room temperature under dark condition for 12hours (for complete carotene extraction). The carotene layer was separated using petroleum spirit in separating funnel, and then made up to 50ml with petroleum spirit; the layer was again passed through a funnel containing calcium chloride to remove any moisture from the layer. The optical density of the layer was measured at 452nm (Ultra-Violet Spectrophotometer) using petroleum spirit as a blank.

The total carotenoid was calculated using:

$$\text{Total carotenoids (mg/100g)} = \frac{3.85 \times \text{optical density of the sample} \times \text{made up volume} \times 100}{\text{weight of sample} \times 1000}$$

2.4.2 Vitamin B_1

0.140g of the sample was dissolved in 5 $cm^3$of anhydrous formic acid and 50 cm^3 of acetic anhydride added, and then titrated immediately with 0.1M $HClO_4$. The end-point was determined potentiometrically within two minutes. Blank titration was also carried out **(**1 cm^3 of 0.1 M $HClO_4$ = 16.37 mg of $C_{12}H_{17}N_5O_4S$).

2.4.3 Vitamin B_2

In a brown-glass of 500 cm^3volumetric flask, 0.65g of the sample was suspended in 5 cm^3 of water which was completely wetted and was then dissolved in 5 cm^3 of dilute sodium hydroxide solution. As soon as dissolution was completed, 100 cm^3 of water and 2.5$cm^3$of glacial acetic acid were added, and were diluted to 500 cm^3 with distilled water. 20 cm^3 of this solution was placed in a 200 cm^3 brown-glass volumetric flask, and further added 3.5 $cm^3$of a 14 g/l solution of sodium acetate and diluted to 200 cm^3 with water. The absorbance was measured at 444 nm.

2.4.4 Vitamin B_3

0.250g of the sample was dissolved in 50 cm^3 of water, and titrated with 0.1M sodium hydroxide, using 0.25cm^3 of phenolphthalein solution as indicator, until a pink colour was obtained. A blank titration was also carried out (1 ml of 0.1 M NaOH = 12.31 mg of $C_6H_5NO_2$).Nicotinic acid

2.4.5 Vitamin B_6

0.150g of the sample was dissolved in 5 cm^3 of anhydrous formic acid, 50 cm^3 of acetic anhydride were also added and titrated with 0.1 M perchloric acid. The end-point was determined potentiometrically. A blank titration was also carried out.
(1 ml of 0.1 M $HClO_4$ = 20.56 mg of $C_8H_{12}ClNO_3$)

2.4.6 Vitamin C

0.150g of the sample was dissolved in a mixture of 10 cm^3 dilute sulfuric acid and 80 cm^3 of carbon dioxide-free water, 1 cm^3 of starch solution was also added and titrated with 0.05 M iodine until a persistent violet-blue colour was obtained (1 cm^3 of 0.05 M I_2 is = 8.81 mg of $C_6H_8O_6$).

2.5 Statistical analysis

Simple statistics such as mean and standard deviation (SD) were used for the analysis of data. Analysis of Variance (ANOVA) was also used to determine levels of significance among parameters determined. SPSS version 20 software was used for the analysis of the results.

III. Results and Discussion

3.1 Proximate analysis

Results for the proximate composition of the raw, boiled-dehulled, and boiled-undehulled Artocarpus altilis seed flour are presented in Table 1. The percentage ash content of the raw was highest (2.49 ± 0.01%), and the least in the boiled-dehulled seeds (2.42 ± 0.02%).

Table 1. Proximate composition (%) of processed Artocarpus altilis seeds

Parameter	Raw	Boiled-dehulled	Boiled-undehulled
Ash	2.49 ± 0.01[a]	2.42 ± 0.02[a]	2.45 ± 0.01[a]
Moisture	8.05 ± 0.01[a]	8.12 ± 0.02[a]	8.19 ± 0.02[a]
Crude Protein	8.12 ± 0.02[a]	17.49 ± 0.01[a]	13.43 ± 0.02[a]
Crude Fibre	2.20 ± 0.01[a]	5.01 ± 0.02[b]	5.38 ±0.01[b]
Carbohydrates	72.66 ± 0.01[a]	59.85 ± 0.02[b]	63.00 ± 0.03[b]
*Energy (Kj/100g)	1650.01 ± 85.00[a]	1577.85 ± 80.00[a]	1572.66 ± 79.00[a]
**Fatty acids	5.98 ± 0.05[a]	5.69 ± 0.04[a]	5.80 ± 0.05[a]

Mean values with the same alphabet within the same row are not significantly different at P = .05;
*Calculated metabolisable energy (kJ/100g^{-1}) (protein x 17 + fat x 37 + carbohydrate x 17), **Calculated fatty acids (0.8 x crude fat).

This was an indication of higher inorganic matter content in the raw sample. The moisture content ranged from 8.05 ± 0.01 % for the raw to 8.19 ± 0.02 % for the boiled-undehulled.

The moisture contents were also similar to the results reported for breadfruit seeds from a rainforest in Calabar [10], but lower than the values reported for Artocarpus communis [14]. The moisture level of food is usually a measure of stability and susceptibility to microbial contamination. High level of moisture content is an indicative of its high perishability. Variation in the moisture content could be attributed to the stage of maturity at which crop was harvested, environmental and storage factors at the time of harvest. Low moisture content of food sample remains an asset in storage and preservation of the nutrients [15].

The crude protein content (17.49 ± 0.01 %) of the boiled-dehulled seeds was higher than those of the raw seeds (8.12 ± 0.02 %) and boiled-undehulled seed (13.43 ± 0.02 %), The removed outer coats contain cellulose, thereby shooting up the crude protein and reducing the carbohydrate content of dehulled seed [16]. These value concords with results reported by [17] and [4] but lower than the values reported by [18].

Crude fat varied in the order of raw (7.48 ± 0.02 %) > boiled-dehulled (7.11 ± 0.01 %) > boiled-undehulled (7.25 ± 0.01 %), while crude fibre varied in decreasing order of boiled-undehulled (5.38 ± 0.01 %), boiled-dehulled (5.01 ± 0.02 %) and raw (2.20 ± 0.01 %). The highest crude fat and crude fibre was recorded in the raw and boiled-undehulled respectively. These results were within the range reported by [17] for crude fat (6.70 to 9.01 %) and higher for crude fibre (1.00 to 3.20 %), except for the raw seeds. However, [18] reported lower crude fibre (1.20 %) and higher crude fat content (8.20 %). The crude fibre has a useful role in providing roughage that aids digestion [15]. The relatively low fat content recorded in the boiled-dehulled and boiled-undehulled will help in increasing the shelf life of the samples by decreasing the chances of rancidity, and will also contribute to the low energy value of the sample [19].

The total carbohydrate contents were observed to be the highest of nutritional content in the sample attaining the highest concentration in the raw sample. This implies that the seed is a good source of carbohydrate which is an energy-giving food [16]. Carbohydrate content of the raw seeds (72.66 ± 0.01 %) was higher than the content (64.95 ± 0.27 %) reported by [16], but less than the content (27.5 %) reported by [18] and within the range (73.26 ± 0.01 %) reported by [10]. The variations in carbohydrates content may be as a result of the

different localities the plant is cultivated as well as difference in the level of drying of the seeds [16]. The moisture, crude protein and crude fibre levels of the boiled-undehulled sample increased on boiling. Nutritional composition of boiled-dehulled and boiled-undehulled samples indicated that ash, crude fat and carbohydrate contents decreased on boiling, while other nutritional components increased on boiling.

The fatty acids of the raw (5.98 ± 0.05 %) sample calculated were relatively higher than for the boiled-dehulled (5.69 ± 0.04 %) and boiled-undehulled (5.80 ± 0.05 %). The metabolisable energy of the raw sample (1650.01 ± 85.00 kJ/100g) was also observed to be higher than for the boiled-dehulled (1577.85 ± 80.00 kJ/100g) and then boiled-undehulled (1572.66 ± 79.00 kJ/100g). Boiling decreased the fatty acids and the energy contents of the boiled-dehulled and boiled-undehulled sample.

3.2 Mineral contents

The results in Table 2 indicated that Na (0.81± 0.04%), K (9.40 ± 1.50%) contents were highest. Boiling and dehulling led to significant decrease in sodium and potassium contents compared to the raw sample. High amount of potassium in the body increases iron utilization. The potassium content of the raw sample (9.40 mg/g) was higher than the 0.83 ± 0.00mg/g reported by [14], but less than the values (588.62 mg/g) reported by [20] and (587mg/g) by [10].

Table 2. Mineral composition (mg/g) of Artocarpus altilis seeds

Element	Raw	Boiled-dehulled	Boiled-undehulled
Na^+	0.81 ± 0.04[a]	0.27 ± 0.02[b]	0.54 ± 0.02[a]
K^+	9.40 ± 1.50 [a]	9.00 ± 1.50 [a]	8.60 ± 1.05 [a]
Ca^{2+}	2.90 ± 0.03 [a]	3.00 ± 0.05 [a]	8.90 ± 1.35 [b]
Mn	0.02 ± 0.00 [a]	0.01 ± 0.00 [a]	0.01 ± 0.00 [a]
Mg	0.96 ± 0.05 [a]	0.99 ± 0.03 [a]	2.97 ± 0.04 [b]
Zn	0.02 0.00[a]	0.02 ± 0.00 [a]	0.02 ± 0.00 [a]
Cr	ND	ND	ND
Pb	ND	ND	ND
Fe	0.15 ± 0.01 [a]	0.25 ± 0.03 [a]	0.16 ± 0.01 [a]
Cu	0.05 ± 0.00 [a]	0.07 ± 0.01 [a]	0.02 ± 0.00[b]
Na/K	0.09 ± 0.002 [a]	0.03 ± 0.00 [b]	0.06 ± 0.00 [a]
Ca/Mg	3.02 ± 0.05 [a]	3.03 ± 0.02[a]	3.00 ± 0.08 [a]

ND = Not detected, Mean values with the same alphabet within the same row are not significantly different (P = .05)

Zn and Mn contents were same for the processed samples, which was in agreement with results reported by [21]. The raw, boiled-dehulled and boiled-undehulled seeds of Artocarpus altilis seeds were richer in Na, K, Ca and Mg than Mn, Cu, Fe and Zn; while Pb and Cr were below detectable limit. The observed differences in the mineral contents might be attributed to the effect of processing, which agrees with the report by [20].

The highest Mg content (2.97 ± 0.04 mg/g) was obtained in the boiled-undehulled sample. These values were within the range reported by [22], but were higher than 0.18±0.00mg/g (Ca), 0.24±0.00 mg/g (Mg) and 0.37 ± 0.00 mg/g (Na^+) reported by [14]. Fe level varied in the order of boiled-dehulled (0.25 ± 0.03 mg/g) > boiled-undehulled (0.16 ± 0.01 mg/g) > raw (0.15 ± 0.01mg/g), while copper occurred in decreasing order of boiled-dehulled (0.07 ± 0.01mg/g) > raw (0.05 ± 0.00 mg/g) > boiled-undehulled (0.02 ± 0.00 mg/g). Fe and Cu levels in the raw sample were within the range reported by [22].

Na/K ratio was the least in the boiled-dehulled (0.03 ± 0.00 mg/g) and highest (0.09 ± 0.002 mg/g) in the raw sample. The Na/K in the body assists in the prevention of high blood pressure. Na/K ratios were less than one in the three samples which is within the acceptable level. Therefore, breadfruit eaten in any of the forms may reduce high blood pressure disease [23]. Ca/Mg ratio for the boiled-dehulled sample (3.03 ± 0.02) was highest and the least in the boiled-undehulled (3.00 ± 0.08 mg/g).

3.3 Vitamin Contents

Vitamins composition of Artocarpus altilis seeds are presented in Table 3. Vitamins content of the processed raw sample (18.9 ± 0 2.50 mg/kg) was higher than the boiled-undehulled sample (14.3 ± 0 2.45 %) and then the boiled-dehulled (11.72 ± 3.00 mg/kg) sample. The decrease in Vitamin C content of boiled-dehulled and boiled-undehulled compared to the raw sample might be attributed to the cooking time which causes the Vitamin C content to be leached easily into the cooking water, or due to the effect of processing (Abiodun and Umeonuorah, 2013). Vitamin A (0.29 ± 0.00 – 0.52 ± 0.01 mg/kg) and riboflavin (0.09 ± 0.00 – 0.2 0 ± 0.02 mg/kg) contents were low for the processed sample. Pyridoxine and thiamine level showed no variation. The highest and the lowest niacin levels were recorded in the raw (1.10 ± 0.08 mg/kg) and boiled-dehulled (0.90 ± 0.05 mg/kg) respectively. Boiling increased the level of Vitamin A (0.47 ± 0.02 mg/kg) and decreased Vitamin C (14.30± 02.45 mg/kg) and niacin (1.02 ± 0.04 mg/kg) contents in the undehulled sample

compared to the raw. A comparison of essential mineral and vitamin composition of Artocarpus altilis seeds with Recommended Dietary Association (RDA) [24] nutritional requirements indicated that the sample is a rich source of potassium, vitamin C, thiamine, calcium and pyridoxine.

Table 3: Vitamins composition (mg/kg) of Artocarpus altilis seeds

Vitamins	Raw	Boiled-dehulled	Boiled-undehulled
Vitamin A	0.29 ± 0.00 [a]	0.52 ± 0.01 [a]	0.47 ± 0.02 [a]
Vitamin C	18.90 ± 2.50 [a]	11.72 ± 3.00 [b]	14.30 ± 0 2.45 [b]
Niacin	1.10 ± 0.08[a]	0.90 ± 0.05 [a]	0.90 ± 0.05 [a]
Pyridoxine	4.35 ± 1.00 [a]	4.35 ± 0.09 [a]	4.35 ± 1.25 [a]
Riboflavin	0.20 ± 0.02 [a]	0.09 ± 0.00 [b]	0.10 ± 0.01[b]
Thiamine	3.46 ± 0.75 [a]	3.46 ± 0.85[a]	3.46 ± 1.25 [a]

Mean values with the same alphabet within the same row are not significantly different (P = .05)

3.4 Statistical analysis

ANOVA for the proximate analysis (Table1) indicated that crude fiber and carbohydrates in boiled-dehulled and boiled-undehulled were significantly different from the raw (P = .05). K, Mn, Zn and Fe (Table 2) were not significantly different. Na in the boiled-dehulled, and Ca, Mg and Cu in the boiled-undehulled were significantly different. From Table 3, Vitamin C and riboflavin in the boiled-dehulled and boiled-undehulled were significantly different from the raw sample. Comparing mineral contents, in the samples, Na, K, Ca and Mn were significantly different (P = .05). Zn in the raw sample was significantly different (P = .05) from the boiled-dehulled and boiled-undehulled. Vitamin C and Niacin were significantly different, whereas pyridoxine and thiamine were not. Riboflavin content for the raw and boiled-undehulled, and boiled-dehulled and boiled - undehulled were not significantly different (P = .05)

IV. Conclusion

The raw breadfruit seeds contained the highest ash (2.49 ± 0.01%), crude fibre (7.48 ± 0.01%), carbohydrates (72.66 ± 0.01%) and fatty acids (5.98 ± 0.05%) contents. Moisture (8.19 ± 0.02) and crude protein (17.11 ± 0.01%) contents were highest in boiled-undehulled and boiled-dehulled respectively. Na^+, K^+, and Mn in raw, Mg^{2+}, Fe and Cu in boiled-dehulled, and Ca (8.90 ± 1.35 mg/kg) and Mg (2.97 ± 0.04 mg/kg) in boiled-undehulled were highest. Dehulling the seeds of the breadfruit increased the crude protein and crude fibre, but decreased moisture, ash, crude fat and total carbohydrate. Boiling decreased Vitamin C, Niacin and riboflavin contents, and has no effect on pyridoxine and thiamine. K^+ and Ca^+ may need to be fortified with Na^+, Mg^{2+}, Fe and Zn when used in food formulation because of their low inherent levels. High K^+, Cu, Fe and low Na^+ contents in dehulled seeds of the breadfruit suggests that the dehulled seeds are more valuable than the hulled seeds when consumed by children. The low Na/K ratio suggests that consuming of the breadfruit may reduce high blood pressure.

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