Optimizing breadfruit processing for nutritional, phytochemical and antioxidant properties: Enhancing food security in Nigeria

Abstract

Hunger is currently one of the leading concerns in Nigeria, with the current increase in insecurity, high fuel cost and transportation, food shortages are expected except huge increases in food production are accomplished. Breadfruit is a low-cost staple meal that can be grown in tropical areas where hunger is widespread. The aim of this study is optimizing breadfruit processing for nutritional, phytochemical and antioxidant properties: enhancing food security in Nigeria. The raw, boiled and toasted forms of breadfruit were used for this study. The vitamins, phytochemicals and antioxidants content were assayed using spectrophotometer while the minerals were determined using standard methods. The findings showed that the concentration (mg/100g) of vitamin A, D, E, and K were significantly higher for the raw form (1.04,0.59,11.58, and 0.05) in comparison to the boiled (0.61, 0.51, 8.68, and 0.02) and toasted (0.08, 0.26, 3.19, and 0.004) respectively. Potassium, zinc, selenium, and calcium contents were significantly higher in the order raw > boiled > toasted. Phytochemical analysis revealed that phenols and alkaloids were significantly higher in the raw (40.13 and 24.54mg/100g) in comparison to the boiled (19.56 and 17.59mg/100g) and toasted (10.35 and 4.48mg/100g). The antioxidant property showed that glutathione and polyphenol contents were significantly higher in the raw (36.67g/ml, 53.46mgGAE/100g) when compared with the boiled (11.24, 34.76) and toasted (3.57, 8.50). The findings showed that the raw had more nutrients in comparison to boiled and toasted. Finally, processing methods influenced the nutritional, phytochemical, and antioxidant properties of breadfruit with the raw having better values.

Keywords: Food processing, nutritional composition, food security, breadfruit, phytochemicals, antioxidant activity

Introduction

Hunger has plagued human civilization since prehistoric times. Given the current population growth, food shortages are expected unless significant increases in food production are achieved[1]. Due to increased food and fuel prices, food security is worsened with over 80% of the world's hungry people living in the tropical regions[2], leading to undernourishment and malnutrition. According to Soifoini et al.[3], food security is ensured when all people have access to enough healthy, nutritious food to meet their nutritional needs and preferences, leading to living active and healthy lives. Breadfruit can be grown in tropical climates, home to many countries with high rates of malnutrition. It offers an opportunity to sustainably boost food production in the regions of the world that needs it the most and can largely prevent food crisis[1].

Breadfruit or *Treculia africana* belongs to the family of Moraceae[4]. It is native to Malayasia and Africa. In Nigeria, it is called "Ukwa" in Igbo, Barafuta in Hausa while in Yoruba, it is called Gberebutu or Jaloke[5]. The plant grows in the tropics and is used to prepare a wide range of dishes. The tree bears fruits for an average of four to six years and is also propagated by root cuttings[5]. Reported of Yumni *et al.*[6], the tree remains evergreen both in wet and dry seasons. It produces fruits that have enormous potential for feeding humans and other domestic animals. A mature African breadfruit tree can produce up to 50 fruits per year, each containing 5-10kg of seeds[7]. According to Soifoini et al.[8], breadfruit is a very versatile food, which can be prepared in many ways. It can be baked, fried, or steamed once fully grown. It can be transformed into flour and could also be preserved by drying or by fermentation process[8].

Due to its rich nutrient composition, breadfruit is a crop of global importance that provides a plethora of nutritional and health benefits[9]. Breadfruit is rich in carbohydrate and amino acids[10]. It is rich in β-carotene and other carotenoids, which protect against heart disease, cancer and vitamin A deficiency[4] as well as strengthen the immune system and supports vision[9]. African breadfruit is rich in vitamin C, promoting immune system function, supports bone integrity, and collagen synthesis[7,9]. It is also high in potassium content[11] for nerve and muscle function, and fiber for gut health[9]. Copper, potassium, magnesium, iron, phosphorous, calcium, manganese, and cobalt are among the minerals found in breadfruit[12]. Flavonoids and phenolics are also abundant in breadfruit[13]. Leng *et al.*[14], demonstrated the antioxidant potential of breadfruit leaves, which can successfully neutralize free radicals. Furthermore, Azli *et al.*[15] demonstrated that the nutritional and antioxidant properties of breadfruit leaves infused at 100^{o}C, is a potential functional food and nutraceutical. According to Sikarwar *et al*.[16] breadfruit has anti-inflammatory, antidiabetic, antioxidant, immunomodulatory, antifungal, and antibacterial properties[16].

Breadfruit has been traditionally used to treat a number of illnesses[17]. According to Buddhisuharto *et al*.[18] it contains bioactive compounds with therapeutic properties. Asthma, low blood pressure, diarrhoea, tongue fungus, skin infections and other diseases are treated with different parts of breadfruit[10]. The leaves are used to treat skin diseases, boils, wounds and fever. The young fruits have a digestive and astringent effect. The ripe fruits are said to have aphrodisiac and laxative properties. The seeds are used to treat diuresis and constipation [49,50]. The wood is used to treat cramps, diabetes, inflammation, and for sedation. In addition to having an antibacterial effect, the latex is also used to treat pharyngitis, and eye diseases. Dried latex not only has a strong androgenic effect, but also helps in snake bites and abscesses. The roots can be used for the treatment of fever, skin disease, diarrhea, and asthma[17]. According to Bennett and Isaiah[7], the water and ethanoic extracts of the root possess anti-hyperglycaemic properties.

In underdeveloped nations, malnutrition represents a significant public health threat[3]. Breadfruit is a fundamental food that aids in combating malnutrition due to its high mineral and carbohydrate content [10,12]. The objective of the study is to optimize breadfruit processing for its nutritional, phytochemical, and antioxidant properties.

Methodology

Sample collection, identification and preparation

Unprocessed seeds of breadfruit were purchased from Mile 3 Market, Port Harcourt, Nigeria. The sample was identified by a taxonomist in the Department of Plant Science & Biotechnology, Rivers State University with voucher number RSUPbH0127. The sample was taken to the laboratory for analysis, weighed and placed into three beakers designated as raw, boiled and toasted. An analytical balance was used to weigh 50g of the fresh sample and transferred to a 250 ml beaker. This was then peeled, yielding a final weight of 34.14g. This peeled sample was placed in a beaker labelled raw. Another 50g was filled with 200ml of water and cooked for an hour at 100^{o}C. After cooling, the boiled sample weighed 44.28g and was placed in a beaker labelled boiled. Finally, another 50g of raw sample was toasted for 10minutes in a dry pot at 60^{o}C before peeling, yielding a weight of 20.69g, this was labelled as fried.

Extraction of Samples

The sample (0.5g) was added into 50ml centrifuge tube. To it was added 10ml distilled water and 2ml alcohol. This was mixed and centrifuged at 4000rpm for 10minutes. The supernatant was taken and used for the analysis. To 1ml of the sample, 4ml of distilled was used to dilute it.

Determination of vitamin B-complex

Vitamin B_1 (Thiamine hydrochloride)

Five milliliters (5 mL) of the standard and sample were allocated into appropriately labeled test tubes. In each test tube, 5 mL of 0.1M NH4OH and 0.5 mL of 4-Amino phenol solution were added and thoroughly mixed. This was allowed to sit for 5 minutes prior to the addition of 10 mL of chloroform. The chloroform layer was subsequently separated. The absorbance was measured at 430 nm using a spectrophotometer.

Vitamin B_2 (Riboflavin)

Five milliliters (5 mL) of the standard and sample solutions were placed in appropriately labeled test tubes. Each test tube received 2 mL of hydrochloric acid (1 M), 2 mL of glacial acetic acid, 2 mL of hydrogen peroxide, 2 mL of potassium permanganate (15% w/v), and 2 mL of phosphate buffer (pH 6.8), which were thoroughly mixed, and the absorbance was measured at 444 nm using a spectrophotometer.

Vitamin B_3 (Nicotinamide)

Two milliliters (2 ml) of the standard, sample, and blank solutions were put in appropriately labeled test tubes. Each test tube received 5 mL of sulphanilic buffer (pH 4.5), 5 mL of water, and 2 mL of cyanogen bromide solution (10% w/v), which were then mixed completely. The absorbance was measured at 450 nm in a spectrophotometer against a blank and recorded every 2 minutes

Vitamin B_5 (Pantothenic acid)

Hydrolysis of standard and sample

Five milliliters (5 mL) of both the standard and sample solutions were transferred to a 50-milliliter volumetric flask. Two milliliters (2 mL) of 1M HCl were introduced into each volumetric flask and thoroughly stirred. The mixture was heated for 5 hours at 69 ± 10°C and subsequently cooled to room temperature. Subsequently, 2 mL of hydroxylamine reagent (7.5% in 0.1M sodium hydroxide) and 5 mL of sodium hydroxide (1M) were included. This was left for five minutes. Hydrochloric acid (1M) was utilized to adjust the pH to 2.7 ± 0.1, and distilled water was employed to make up volume.

Procedure

Five milliliters (5 mL) of the standard and sample hydrolysis solutions were placed in labeled test tubes. A 1% ferric chloride solution in water was introduced into each test tube and thoroughly mixed. Absorbance was measured at 500 nm subsequent to the removal of air bubbles.

Vitamin B_6 (Pyridoxine hydrochloride)

In well-labeled test tubes, 2 mL of the standard and sample solution were added. Each test tube was filled with 1 mL ammonium buffer (in water), 1 mL of 20% sodium acetate (in water), 1 mL of 5% boric acid (in water), and 1 mL dye (2,6- di-cholroquinine chorimide) solution. The absorbance was recorded at 650 nm.

Vitamin B_7 (Biotin)

The sample (500 mcg) was weighed and transferred into a 100 mL volumetric flask, subsequently dissolved in 10 mL of dimethyl sulfoxide. The flask was subjected to heating for 5 minutes at a temperature range of 60^0 to 70^0 C. The volume was made up to the indicated mark with distilled water. The sample was filtered, and absorbance was measured at 294 nm.

Folic Acid (Vitamin B_9)

In labeled test tubes, 2 mL of both the standard and sample solutions were introduced. Each test tube received 2 mL of 0.02% potassium permanganate solution, 2 mL of 2% sodium nitrate solution, 2 mL of 4M hydrochloric acid solution, 1 mL of 5% ammonium sulphamate solution, and 1 mL of 0.1% N,N-diethyl aniline dye solution in isopropyl alcohol, which were mixed thoroughly and allowed to stand at room temperature for 15 minutes. The absorbance was measured at 535 nm.

Vitamin B_{12} (Cyanocobalamin)

One microgram (1 mcg) of sample was taken into 25 ml volumetric flask and dissolved with 10 mL of water. To it was added 1.25 gm of dibasic sodium phosphate, 1.1 gm of anhydrous citric acid, and 1.0 gm of sodium metabisulphate. The volume was made up to the mark with water. The solution was autoclaved at 121^{O}C for 10 minutes. This was filtered and the absorbance measured at 530 nm.

Determination of Fat-Soluble Vitamins and Vitamin C Contents

Vitamin A Acetate (Retinol) was determined as described by Codex[19]. Vitamin D_3 (Cholecalciferol) was determined according to the method described by Kumar et al.[20] Vitamin E and Vitamin K was done as cited by Peters and Chibueze[21]. AOAC[22] was adopted for vitamin C analysis.

Estimation of mineral content

The heavy metals content was determined using flame atomic absorption spectrophotometer (mode: S4=71096) as cited by Tuzen[23] although slightly modified.

Determination of the phytochemicals

Tannin content of the sample was determined by Folin-Denis method with slight modifications as cited by Oloyede et al.[24] Flavonoid was determined using the method described by Harbone as cited by Sembiring et al.[25] Total Phenol was determined using the Folin-Ciocalteu spectrophotometric method as cited by Barba and Malik[26]. Obadoni and Ochuko[27] method was used for saponin determination. Alkaloid was estimated according to Inuwa et al[28].

Determination of antioxidants

For Polyphenol determination, the fat free sample used for its assay was extracted using soxhlet extraction as described by Murugan and Parimelazhagan[29] and the absorbance was read at 550 nm. Catalase activity was measured as described by Khan et al [30] while Tipple and Rogers[31] method was used to estimate glutathione concentration although slightly modified.

Statistical analysis

All data were analyzed statistically and reported as mean ± standard deviation. One-way analysis of variance was utilized to determine statistical difference between the groups, which was followed by a post hoc Turkey Test. A $p < 0.05$ was deemed statistically significant. SPSS (window version 21) was used for the statistical analyses.

Results and Discussion

Table 1: Fat Soluble Vitamins and vitamin C content of raw and processed breadfruit

Parameters (mg/100g)	Raw	Boiled	Toasted	FAO/WHO[32] /day	FAO/WHO[33] /day
Vit A	1.04 ± 0.002^{a}	0.61 ± 0.001^{bc}	0.08 ± 0.001^{bc}	375-850µg or 0.375-0.850mg	580µg or 0.580mg
Vit D	0.59 ± 0.44^{a}	0.51 ± 0.002^{b}	0.26 ± 0.003^{c}	5-15µg or 0.005-0.015mg	5-15µg
Vit E	11.58 ± 0.001^{ac}	8.68 ± 0.002^{ab}	3.19 ± 0.002^{bc}	2.7-10mg	9mg
Vit K	0.05 ± 0.002^{a}	0.02 ± 0.001^{bc}	0.004 ± 0.001^{ac}	5-55µg or 0.005-0.055mg	-
Vit C	9.62 ± 0.001^{a}	5.28 ± 0.002^{b}	1.439 ± 0.002^{c}	25-70mg	45-100mg

Data are denoted as mean ± standard deviation of triplicate values, values in a row bearing different alphabetical superscripts differ significantly at $p < 0.05$.

The fat-soluble vitamins and vitamin C content of raw and processed breadfruit is shown on Table 1. The concentration (mg/100g) of vitamin A ranged from 0.08-1.04, vitamin D (0.26-0.59), vitamin E (3.19-11.58), vitamin K (0.004-0.05), and vitamin C (1.439-9.62). The order significantly was as follows: raw > boiled > toasted. The vitamin A concentration in this study for the raw and boiled, were within the range reported by Wekhe et al.[34] Soifoini et al.[8] reported similar vitamin C values as obtained in this study. Frances and Johnson[35], had similar Vitamin A and E values, lower Vitamin C and higher Vitamin D values when compared to this study. The vitamin D result for this study was higher than the FAO/WHO[33] values. Vitamin E for the raw exceeded the FAO/WHO[33] threshold, whereas processed forms were lower. Vitamin A in the raw and boiled forms, were higher than the FAO/WHO[32] values, while the toasted form was lower. The FAO/WHO[32,33] recommended daily allowance of vitamin C was greater than that obtained in this study. This suggests that consumption of breadfruit can meet the nutritional needs for Vitamin A, E and D. Vitamin E is an antioxidant that helps to protect the membranes of the cells in the body from harm caused by oxygen species. It may also minimize the risk of heart disease and reduce eye inflammation. Vitamin C is beneficial for the immune system, and helps the body maintain proper calcium and phosphorus levels[35].

Table 2. Vitamin–B complex composition of African bread fruit prepared with different processing methods

B–Complex Vitamins (mg/100g)	Raw breadfruit	Boiled breadfruit	Toasted breadfruit	FAO/WHO[32] Recommended nutrient intake
Thiamin	1.18 ± 0.00^{a}	0.83 ± 0.00^{b}	0.28 ± 0.00^{c}	0.2-0.9mg/day – infants & children 1.1-1.5mg/day – adult
Riboflavin	0.40 ± 0.00^{a}	0.06 ± 0.00^{b}	0.02 ± 0.00^{c}	0.3-0.9mg/day – infants & children 1.1-1.6mg/day – adult
Niacin	0.08 ± 0.00^{a}	0.06 ± 0.00^{b}	0.03 ± 0.00^{c}	2-12mgNES/day –– infants & children 14-17mg/day - adult
Pantothenic acid	0.13 ± 0.00^{a}	0.74 ± 0.00^{b}	0.34 ± 0.00^{c}	1.7-4.0mg/day – infants & children 5-7mg/day - adult
Pyridoxine	0.06 ± 0.00^{a}	0.03 ± 0.00^{b}	0.01 ± 0.00^{c}	0.1-1.0mg/day – infants & children 1.3-2.0mg/day – adult
Biotin	0.12 ± 0.00^{a}	0.08 ± 0.00^{b}	0.04 ± 0.00^{c}	5-20µg/day – infants & children 30-35µg/day – adult or 0.005-0.02mg/day - infants & children 0.03-0.035mg/day- adult
Folic acid	0.11 ± 0.00^{a}	0.05 ± 0.00^{b}	0.01 ± 0.00^{c}	80-300µg/day – infants & children 400-600µg/day - adult or 0.08-0.30mg/day –infants & children 0.40-0.60mg/day –adult
Cobalamin	0.02 ± 0.00^{a}	0.01 ± 0.00^{b}	0.01 ± 0.00^{b}	0.4-1.8µg/day – infants & children 2.4-2.8µg/day – adults Or 0.00004-0.0018mg- infants & children

				0.0024-0.0028mg/day-adults

Data are denoted as mean ± standard deviation of triplicate values, values in a row bearing different alphabetical superscripts differ significantly at $p < 0.05$.

Table 2 shows the B-complex vitamins composition of the African bread fruit prepared with different processing methods. The B-complex vitamins were relatively low with the raw having significantly higher concentration than the boiled and the toasted, with the exception of vitamin B_5, where the order was boiled (0.74 mg/100g) > toasted (0.34) > raw (0.13). The range for thiamin was 0.28-1.18, riboflavin (0.02-0.40), niacin (0.03-0.08), pantothenic (0.13-0.74), pyridoxine (0.01-0.06), biotin (0.04-0.12), folic acid (0.01-0.11), and cobalamin (0.01-0.02). The B-complex vitamins were relatively low. The value of thiamin (vitamin B_1) was within the range reported by Wekhe et al.[34] In comparison to this study, Olapade and Umeonuorah[36], had lower vitamin B_1 but higher levels of B_2 (riboflavin), and niacin. Bioton and cobalamin levels in this investigation were above the FAO/WHO[32] recommended nutrient intake. Thiamin, in the raw form was within the FAO/WHO[32] while riboflavin, niacin, pantothenic acid, pyridoxine and folic acid was lower than the FAO/WHO[32] recommended nutrient intake. The findings show that, while African breadfruit contains B-complex vitamins, their levels are relatively low. The highest levels are found in the raw form, highlighting the nutritional benefits of eating breadfruit fresh or slightly processed. The decrease in B-vitamin content due to boiling and toasting implies that these cooking methods can drastically reduce the availability of these vital vitamins.

Table 3. Mineral composition of raw and processed *Treculia africana* (African breadfruit)

Mineral (mg/100g)	Raw breadfruit	Boiled breadfruit	Toasted breadfruit	FAO/WHO[33]	FAO/WHO[32]
Calcium (Ca)	170.147 ±0.09 ^{a}	143.71 ± 0.13 ^{b}	117.46 ± 0.16^{c}		300-1200mg/day
Iron(Fe)	4.56 ± 0.24 ^{a}	3.08 ± 0.06 ^{b}	2.32 ± 0.13^{c}	14-43mg	-
Magnesium(Mg)	98.03 ± 0.03 ^{a}	64.21 ± 0.08 ^{b}	53.41 ± 0.25 ^{c}	240-300mg	26-270mg/day
Phosphorus (P)	54.97 ± 0.05 ^{a}	42.28 ± 0.13 ^{b}	38.07 ± 0.11 ^{c}	700mg	-
Potassium (K)	346.12 ± 0.05 ^{a}	311.43 ± 0.16 ^{b}	274.65 ± 0.42 ^{c}	-	-
Selenium (Se)	46.03 ± 0.06 ^{a}	34.08 ± 0.04 ^{b}	21.45 ± 0.12 ^{c}	30µg or 0.030mg	6-42µg/day or 0.006-0.042mg

Sodium (Na)	4.23 ± 0.05 ^{a}	2.75 ± 0.05 ^{b}	2.21 ± 0.12 ^{c}	-	-
Zinc(Zn)	7.28 ± 0.12 ^{a}	5.00 ± 0.05 ^{b}	3.44 ± 0.32 ^{c}	3-6mg	-
Iodine (I)	3.62 ± 0.12 ^{a}	1.82 ± 0.11 ^{b}	0.85 ± 0.04 ^{c}		90-200µg/day Or 0.09-0.20mg
Molybdenum(Mo)	0.42 ± 0.02 ^{a}	0.25 ± 0.03^{b}	0.15 ± 0.01 ^{c}	45µg or 0.045mg	-

Data are denoted as mean ± standard deviation of triplicate values, values in a row bearing different alphabetical superscripts differ significantly at $p < 0.05$.

African breadfruit had high concentration of potassium, calcium, magnesium and selenium than the other minerals studied (Table 3). Potassium levels (346.12) were highest in raw, boiled (311.43), and toasted (274.65) forms, with significant differences. Molybdenum concentrations were the lowest. The order for minerals is as follows: raw > boiled > toasted. The concentration (mg/100g) of calcium was in the range (117.46-170.14), Fe (2.32-4.56), Mg (53.41-98.03), P (38.07-54.97), selenium (21.45-46.03), Na (2.21-4.23), Zn (3.44-7.28), I (0.85-3.62), and Mo (0.15-0.42). Mbah et al.[37], found similar Mg and Ca concentrations, but lower K and higher Fe concentrations than this study. Osabor et al.[38] had lower Fe but higher Zn, Mg, Ca, and Na concentration when compared with this study. Soifoini et al[8] studied breadfruit flour and had less Fe and Mg but more Ca and Na than this study. In the same vein, Frances ad Johnson[35] found higher Ca, Mg, Fe, and Na but lower P and K levels than this study. Ajah et al. [39] did a research on the mineral content of breadfruit fruit and the leaf, and obtained higher K, Ca, P, and Zn concentration in comparison to this present investigation. The values obtained in this study for Zn, Mo, and Se were higher than the FAO/WHO[33] values, while Mg, Fe, and P were lower. The value of iodine was higher than the FAO/WHO[32] recommended daily allowance while Ca content was lower. Potassium level was also lower than the WHO[40] recommended nutrient intake of (3510 mg/day) for adults. This discrepancy could be explained by the plant's different characteristics, mineral uptake rate, and soil makeup. A plant's mineral content is also determined by its species and the cultural procedure used during planting as obtained by Frances and Johnson[35]. Furthermore, the reduction in mineral content in the processed form when compared to raw was similar to what Souza et al.[41] reported. This result implies that breadfruit can be recommended for Zn, Mo, Se, and I intake since it meets FAO/WHO[32,33] recommended daily allowance.

Table 4. Phytochemical composition of breadfruit processed by different preparatory methods

Parameters	Raw	Boiled	Toasted
Carotenoid (µg/100g)	11.58± 0.25^{a}	7.41 ± 0.12^{b}	2.95 ± 0.06^{c}

Saponins (%)	5.30± 0.24^{a}	2.19 ± 0.07^{b}	0.17 ± 0.008^{c}
Phenols (mg/100g)	40.13 ± 1.13^{a}	19.56 ± 0.17^{b}	10.35 ± 0.17^{c}
Alkaloid (mg/100g)	24.54 ± 0.35^{a}	17.59 ± 0.30^{b}	4.48 ± 0.34^{c}
Tannin (mg/100g)	4.34 ± 0.30^{a}	1.39 + 0.02^{b}	0.28 ± 0.00^{c}
Flavonoid (mg/100g)	16.14 ± 0.05^{ab}	7.68 ± 0.24^{b}	1.64 ± 0.14^{c}

Data are denoted as mean ± standard deviation of triplicate values, values in a row bearing different alphabetical superscripts differ significantly at $p < 0.05$.

The Phytochemical composition of breadfruit processed by different preparatory methods (table 4) revealed the presence of carotenoid, saponins, phenols, alkaloids, and tannins, all of which were significantly higher in raw > boiled > toasted. Phenol was the highest in all three forms. The phytochemical ranges include carotenoid (2.95-11.58 μg/100g), saponins (0.17-5.30%), phenols (10.35-40.13 mg/100g), alkaloids (4.48-24.54 mg/100g), tannin (0.28-4.34 mg/100g), and flavonoid (1.64-16.14 mg/100g). The saponin concentration was identical to that found by Umezuruike[42]. When compared to this study, Ojimelukwe and Ugwuona[43] exhibited equal saponin levels but lower alkaloid value. Similarly, Obijekwu et al.[44] found higher saponin and tannin concentrations in stem, leaf, seed, and root of breadfruit, but a similar range of alkaloid, phenol, and flavonoid levels in comparison to this study. The presence of these phytochemicals indicated the plants' therapeutic capabilities. The significant concentration of phenols and saponin in the raw demonstrated the plants' antiseptic characteristics and suggests its usage as an immune booster, as seen in the study of Obijekwu et al.[44] Confirming the phenolic contents discovered in this investigation, the raw breadfruit revealed greater potential to scavenge radicals, as indicated in the work of Nascimento et al.[45] Furthermore, the decrease in saponin, tannin, and flavonoid levels in the processed forms when compared to the raw form, is consistent with the findings of Ijeh et al.[46], who discovered similar decrease in breadfruit when traditional processing methods were applied in its preparation.

Table 5 Antioxidant activity of breadfruit processed by different preparatory methods

Parameters	Raw	Boiled	Toasted
Glutathione (g/ml)	36.67 ± 0.20[a]	11.24 ± 0.09[ab]	3.57 ± 0.06[bc]
Catalase (%)	28.68 ± 0.24[a]	12.95 ± 75[b]	4.94 ± 0.07[c]
Polyphenol (mg GAE/100g)	53.46 ± 0.28[a]	34.76 ± 0.26[b]	8.50 ± 0.33[c]

Data are denoted as mean ± standard deviation of triplicate values, values in a row bearing different alphabetical superscripts differ significantly at $p < 0.05$.

Table 5 demonstrates the antioxidant activity of breadfruit processed by different methods. The concentration of glutathione, polyphenol, and catalase activity was significantly increased from raw > boiled > toasted. The concentration of polyphenol was (8.50-53.46mg GAE/100g), glutathione (3.57-36.67g/ml), and catalase activity was (4.94-28.68%). Antioxidants are bioactive molecule that can bind to free radicals and highly reactive molecules, preventing cell damage[47]. Phenolic nutraceuticals have been identified as potent antioxidants in health promotion[14]. The raw breadfruit fruit were considered to have moderate radical scavenging activity as obtained by Vianney et al.[48] This investigation found that processing had an effect on breadfruit's antioxidant activity.

According to the findings in this study, breadfruit, particularly in its raw form, is a rich source of several vitamins (A, D, and E), minerals, and phytochemicals with antioxidant properties. Breadfruit nutritional benefits suggest to its potential as a functional food that can help meet dietary demands, notably vitamins that support immune function and cell protection. For its application, breadfruit can be promoted as a healthy food option in dietary guidelines, especially in areas where it is a staple food. Also, the antioxidant properties may lead to its inclusion in functional food products aimed to improve health prevent disease. Furthermore, it could encourage culinary inventions that uses breadfruit to prepare them in methods that preserve its nutritional benefits.

The limitations of the study include that the impacts of various cooking procedures on the phytochemical retention were not thoroughly investigated. Also, differences in soil composition, plant species, and growth conditions could affect the nutrient content, causing the study's result to vary. It is recommended that breadfruit should be consumed in its raw or slightly processed form to maximise nutrient intake. Also, more techniques for preserving the nutritional value of breadfruit during processing should be explored.

Conclusion

Breadfruit is a valuable nutritious source, providing a variety of vitamins, minerals, and antioxidants, especially in the raw form. While processing diminishes nutritional and antioxidant concentrations raw breadfruit still has considerable health advantages. Promoting its consumption may improve dietary diversity and nutrient intake, especially in places who rely on it as a food source. To realize its full potential, more research into its health benefits and preservation methods is needed.

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References

1. Jones AMP, Ragone D, Tavana NG, Bernotas DW, Murch SJ. Beyond the Bounty: Breadfruit (Artocarpus altilis) for food security and novel foods in the 21st Century. Ethnobotany Research & Application. 2011: 9:129-149. www.ethnobotanyjournal.org/vol9/i1547-3465-09-129.
2. Turi CE, Liu Y, Ragone D, Murch SJ. Breadfruit (Artocarpus spp.): A Traditional Crop with the Potential to Prevent Hunger and Mitigate Diabetes in the Tropics. Trends in Food Science & Technology. 2015; doi: 10.1016/j.tifs.2015.07.014.
3. Soifoini T, Donno D, Jeannoda V, Rakoto DD, Msahazi A, Farhat SMM, Oulam MZ, Beccaro GL. Phytochemical Composition, Antibacterial Activity, and Antioxidant Properties of the Artocarpus altilis Fruits to Promote Their Consumption in the Comoros Islands as Potential Health-Promoting Food or a Source of Bioactive Molecules for the Food Industry. Foods. 2021; 10: 2136. https:// doi.org/10.3390/foods10092136
4. Mehta KA, Quek YCR, Henry C J. Breadfruit (Artocarpus altilis): Processing, nutritional quality, and food applications. Frontiers in Nutrition. 2023; 10(1156155)1-13. doi: 10.3389/fnut.2023.1156155
5. Barber LI, Emelike NJT, Sunday BN. “Utilization of Breadfruit in Low Fat Cookie Formulation.” Journal of Food and Nutrition Research. 2016; 4 (10): 658-663. doi: 10.12691/jfnr-4-10-5.
6. Yumni GG, Primtasari R, Afifah N N, Sumantri S. Chemometric Analysis of Ethanol Extract of Breadfruit Leaves (Artocarpus altilis) from Various Regions in Central Java. Jurnal Kefarmasian Indonesia. 2024; 14(2), 167-175. DOI: https://doi.org/10.22435/jki.v14i2.6647
7. Bennett V, Isaiah TD. Proximate, Nutritional and Phytochemical Analysis of Treculia africana (African Breadfruit) Decne in South-South, Nigeria. World Journal of Innovative Research. 2022; 12 (4): 19-23. https://doi.org/10.31871/WJIR.12.4.10
8. Soifoini T, Donno D, Jeannoda V, Rakotoniaina E, Hamidou S, Achmet MS, Solo R N, Afraitane K, Giacoma C, Beccaro G. Bioactive compounds, Nutritional Traits and antioxidant properties of Artocarpus altilis (parkinson) fruits: Exploring a potential functional food for food security on the Comoros Islands. Journal of Food Quality. 2018; (1):5697928. Doi:10.1155/2018/5697928
9. Bawa SH, Webb M. Nutritional and health effects of the consumption of breadfruit. Tropical Agriculture. 2016; 52-69

10. Pradhan C, Mohanty M, Rout A. Phytochemical screening and comparative bioefficacy assessment of Artocarpus altilis leaf extracts for antimicrobial activity. Frontiers in Life Science. 2012: 6(3–4): 71–76, http://dx.doi.org/10.1080/21553769.2013.765811
11. Appiah F, Oduro I, Ellis WO. Nutritional composition of breadfruits (*Artocarpus spp.* and *Treculia africana*) in Ghana. Acta Hortic. 2016; 1128. DOI 10.17660/ActaHortic.2016.1128.3
12. Sharma S, Sharma A, Verma R. The nutritional aspects and food applications of Artocarpus altilis starch: A review. International Journal of Science and Research Archive. 2024; 12(01), 3088–3097. https://doi.org/10.30574/ijsra.2024.12.1.1084
13. Geraldino BR, Lorenzo HLF, Empinado RR, Almonguera JE, Lumayno AA, Ederio TN. Antioxidant Properties and Antibacterial Activity of Breadfruit (Artocarpus altilis) Bark and Leaf Extract against Staphylococcus Aureus and Escherichia Coli. *International Journal of Current Science Research and Review*. 2024; 7(5), 3165-3173. DOI: 10.47191/ijcsrr/V7-i5-77.
14. Leng LY, Nadzri NB, Yee KC, Razak BN, Shaari AR. Antioxidant and Total Phenolic Content of Breadfruit (Artocarpus altilis) Leaves. MATEC Web of Conferences.2018; 150; (06007)1-4. https://doi.org/10.1051/matecconf/201815006007
15. Azli SSN, Bakar AFM, Sanusi SB, Awang-Kanak F. Nutritional, phytochemical, antioxidant activity and sensory attributes of herbal infusion from sukun (Artocarpus altilis) leaf. Proceedings of the 3rd International Conference on *Applied Science and Technology* (ICAST'18) AIP Conference Proceedings. 2016; 020030-1–020030-6; https://doi.org/10.1063/1.5055432
16. Sikarwar MS, Hui BJ, Subramaniam K, Valeisamy DB, Yean LY, Balaji K. A Review on Artocarpus altilis (Parkinson) Fosberg (breadfruit). Journal of Applied Pharmaceutical Science. 2014; 4 (08): 091-097. DOI: 10.7324/JAPS.2014.40818
17. Mohanty M, Pradhana C. A Review on Phytochemistry, Bio-Efficacy, Medicinal and Ethno Pharmaceutical Importance of Artocarpus altilis. Human Journals. 2015; 3 (1): 219-231. www.ijppr.humanjournals.com
18. Buddhisuharto AK, Pramastya H, Insanu M, Fidrianny I. An Updated Review of Phytochemical Compounds and Pharmacology Activities of Artocarpus genus. Biointerface Research in Applied Chemistry. 2021; 11 (6): 14898 – 14905. https://doi.org/10.33263/BRIAC116.1489814905
19. Codex. recommended methods of analyisis and sampling CXS 234-1999. 1999
20. Kamel S. M., Alboudrees H. A. & Alofaibi H. C. evaluation of Vitamin D3 content in selected dried, canned and smooked fish. Nutritional medicine & diet care. 2022*;* 8:56. Doi:10.23937/2572-3278/1510056
21. Peter DE, Chibueze I. Nutrient's composition of costus lucanusianus stem. GSC Biological and pharmaceutical sciences. 2022; 8(2): 070-081. https://doi.org/10.30574/gscbps.2022.18.2.0035
22. Association of Official Analytical Chemists (AOAC). Official Methods of Analysis. 22nd ed. 2019.

23. Tuzen M. Determination of heavy metals in soil, mushroom and plant samples by atomic absorption spectrometry. Michrochemical Journal. 2003; 74: 289-297. Doi:10.1016/S0026-265X(03)000035-3.
24. Oloyede OB, Salau AK, Akeusola RT, Ganiyu OT, Azeez L, Ogunbode SM. Phytochemical content, radical scavenging and antibacterial properties of aqueous extract of *Jatropha curcas*

Linn leaves. Fountain Journal of Natural and Applied Sciences, 2012; 1(1):41-48. Doi: 10.53704/fujnas.vlil.33
25. Sembiring EN, Elya B, Sauriasari R. Phytochemical screening, total flavonoid and total phenolic content and antioxidant activity of different parts of *Caesalpinina bonduc (L.) Roxb.* Pharmacognosy Journal. 2018; 10 (1): 123-127.
26. Baba SA, Malik SA. Determination of total phenolic and flavonoid content, antimicrobial and antioxidant activity of a root extract of Arisaema jacquemontii Blume. Journal of Taibah University for Science. 2015; 9(4): 449-454. http://dx.doi.org/10.1016/j.jtusci.2014.11.001
27. Obdoni BO, Ochuko PO. Phytochemical studies and comparative efficacy of the crude extracts of some homostatic plants in Edo and Delta States of Nigeria. Gobal Journal of Pure & Applied Science. 2001; 8:203-208.
28. Inuwa HM, Aina VO, Gabi B, Aimola I, Toyin A. Comparative Determination of Antinutritional Factors in Groundnut Oil and Palm Oil. Advance Journal of Food Science and Technology. 2011; 3(4): 275-279
29. Murugan R, Parimelazhagan T. Comparative evaluation of different extraction methods for antioxidant and anti-inflammatory properties from Osbeckia parvifolia Arn. – An in vitro approach. Journal of King Saud University – Science. 2013. http://dx.doi.org/10.1016/j.jksus.2013.09.006
30. Khan S, Rehman MU, Khan MZI, Kousar R, Muhammad K, Haq IU, Ijaz KM, Almasoud N, Alomar TS, Rauf A. In vitro and in vivo antioxidant therapeutic evaluation of phytochemicals from different parts of Dodonaea viscosa Jacq. Frontiers in Chemistry. 2023; 11:1268949. doi: 10.3389/fchem.2023.1268949
31. Tipple TE, Rogers LK. Methods for the Determination of Plasma or Tissue Glutathione Levels. Methods Mol Biol. 2012; 889: 315–324. doi:10.1007/978-1-61779-867-2_20.
32. FAO/WHO. Vitamin and mineral requirements in human nutrition. World Health Organization and Food and Agriculture Organization of the United Nations. 2004
33. FAO/WHO. Codex nutrient reference values. Rome. FAO and WHO by Lewis J. 2019
34. Wekhe OE, Chuku EC, Nmom FW. Determination of Nutrient Composition and Associated Spoilage Fungi of Different Varieties of Breadfruit. International Journal of Research and Innovation in Applied Science (IJRIAS*)*. 2020; V(XI): 1-4. www.rsisinternational.org
35. Frances EC, Johnson OO. Assessment of Proximate, Vitamins and Minerals of African Breadfruit Seed (*Treculia africana*). Journal of Global Ecology and Environment. 2022; 16(2): 28-36. DOI: 10.56557/JOGEE/2022/v16i27677
36. Olapade AA, Umeonuorah UC. Mineral, Vitamin and Antinutritional Content of African Breadfruit (Treculia africana) Seeds Processed with Alum and Trona. *IOSR* Journal of Environmental Science, Toxicology and Food Technology. 2013; 5(5): 71-78. www.Iosrjournals.Org
37. Mbah PE, Mfoniso EU, Ukpong SU, Sunday PU. (2022) Comparative Evaluation of Nutrient Composition of Bread Fruit Flour (Artocarpus altilis). International Journal of Research Publication and Reviews. 2022; 3(1): 812-816. www.ijrpr.com
38. Osabor VN, Ogar DA, Okafor PC, Egbug GE. Profile of the African breadfruit (Treculia africana). Pakistan Journal of Nutrition. 2016; 8(7): 1005-1008.
39. Ajah O, Chimee CCN, Unegbu CC. Fabrication of Breadfruit Dehuller and Comparative Quality Assessment of the Dehulled African Breadfruit (*Treculla Africana*). World Journal of Pharmaceutical Research. 2022; 11 (11): 1715-1723. DOI: 10.20959/wjpr202211-25688

40. WHO. Guideline: Potassium intake for adults and children. Geneva, World Health Organization (WHO). 2012.
41. Souza CT, Soares SA, Queiroz AFS., Santos AMB, Ferreira SLC. Determination and evaluation of the mineral composition of breadfruit (*Artocarpus altilis*) using multivariate technique. Microchemical Journal. 2016; 128:84-88. http://dx.doi.org/10.1016/j.microc.2016.04.001
42. Umezuruike CA. (2019). Breadfruit Research and opportunities for Future Commercial Development. International journal of Horticulture Agriculture and Food Science (IJHAF). 2019; 3(4): 165- 172. https://dx.doi.org/10.22161/ijhaf.3.4.2
43. Ojimelukwe PC, Ugwuona FU. The traditional and medicinal use of African breadfruit (Treculia africana Decne): an underutilized ethnic food of the Ibo tribe of South East, Nigeria. Journal of Ethnic Foods, 2021; 8:21, 1-13. https://doi.org/10.1186/s42779-021-00097-1
44. Obijekwu EJ, Izundu AI, Ugwoke CE. The phytochemical constituents of jackfruit (Artocarpus heterophyllus Lam) and African breadfruit (Treculia africana Decne). IAA Journal of Applied Sciences. 2022; 8(1):69-75. www.iaajournals.org
45. Nascimento TP, Santos BCM, Abreu JP, Almeida ILGT, Feijó MBS, Teodoro JA, Ferreira LSM, Cameronc LC, Koblitza BMG. Effects of cooking on the phytochemical profile of breadfruit as revealed by high resolution UPLC–MS^E**.** Journal of the Science of Food and Agriculture. 2020; 100: 1962–197. DOI 10.1002/jsfa.10209
46. Ijeh I, Ejike EC, Nkwonta OM, Njoku BC. Effect of Traditional Processing Techniques on the Nutritional and Phytochemical Composition of African Bread-Fruit (Treculia africana) Seeds. J. Appl. Sci. Environ. Manage. 2010; 14(4): 169 – 173. www.bioline.org.br/ja
47. Devi M, Soekopitogo S, Wibowotomo B, Merawati D. Study of antioxidant activity in Sinom drinks from breadfruit (*Artocarpus altilis*) leaves. Advances in Social Science, Education and Humanities Research. 2018; 242:7-12
48. Vianney YM, Putra DES, Purwanto MGM. Antioxidant and toxicity activity of aqueous extracts from various parts of breadfruit and breadnut. International Journal of Fruit Science. 2020; 20 (3): S1639-S1651, DOI: 10.1080/15538362.2020.1828222
49. Djan , Michael Atuahene. 2023. “Urban Food Security: Examining the Unique Challenges and Opportunities Associated with Ensuring Food Security in Urban Areas”. European Journal of Nutrition & Food Safety 15 (9):42-52. https://doi.org/10.9734/ejnfs/2023/v15i91335.
50. Chaudhary, Jyoti, Kalpna Thakur, Rohit Shelar, Rajat Singh, Rimpika, Sarita Devi, and Swati Verma. 2024. “Food Security in India: Milestones Achieved So Far”. Archives of Current Research International 24 (5):480-93. https://doi.org/10.9734/acri/2024/v24i5725.