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Utilization patterns and the effect of processing on nutritional, functional, phytochemical and anti-oxidant properties of Jackfruits (*Artocarpus heterophyllus*) seeds in Tanzania

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Abstract

Jackfruit seeds are rich in nutrient such as carbohydrates, proteins, minerals and polyphenols. Yet, they are hugely underutilized in the country at present. The study aimed to establish the utilization patterns and effects of processing (boiling, soaking and roasting) on nutritional, phytochemical and ant- properties of Jackfruits seeds. A total of 384 jackfruit farmers were interviewed across the surveyed districts by using a semi-structured questionnaire. Following processing, all seeds were dried, milled and analyzed by using standard methods. The study revealed that, majority (70%) of farmers use fresh seeds, with the sole reason ofrefreshment as a nut (91%). All farmers were not aware whether seeds can be processed into flour. Also, roasting (38%) and boiling (32%) of seeds were preferred traditionally as processing methods. After seed processing, moisture values ranged from 5.75 to 8.86% with soaked seeds having the lowest values. Fat content ranged from 0.65 to 1.63% with higher loss in roasted and all boiled samples. Processed seeds were rich in fibers (17.56%-24.35%), ash (3.43%-4.32%) and proteins (11.40%-12.95%). Carbohydrate content ranged from 43.83 to 70.22% with soaked seeds being the best. All processed seeds were rich in minerals, mostly K, P, Ca, Na and Zn the least. Flavonoids, phenolics and antioxidant activities were significantly reduced in all boiled samples. There was a 50% reduction of tannins in boiled (for 30 and 45 minutes) and roasted seeds. Also, trypsin inhibitors were significantly reduced in boiled seeds depending on the boiling time.. The flour sample from the processed seeds had good solubility, swelling, bulky density and oil absorption capacities. With suitable functional properties, optimal nutrients and reduced anti-nutrients levels, the processed seed flour by boiling for 45 minutes could be considered for value addition in food industry.

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Introduction

Jackfruit tree (*Artocarpus heterophyllus* Lam.) is among of underutilized fruits that belongs to the family Moraceae and originated in the rainforest of Western Ghats of India. It is popular in several tropical, sub-tropical countries and some part of Africa (Nagala, Yekula, and Tamanam (2013). Jackfruit has three main parts: the pulp (29%), seeds (12%) and fibrous part (54%) (Eke-Ejiofor, Beleya, & Onyenorah, 2014). Depending on the varieties and growing area, the full matured fruits contain between 100 and 550 seeds which are light brown in color, oval or rounded in shape, and enclosed in a white aril encircling a thin brown endosperm which cover the fresh white cotyledons. However, there is no any relationship between the fruits size and quantity of seed (Madrigal-Aldana *et al*., 2011).

Jackfruit seeds are good source of nutrients including starch, protein, fibers, minerals and phytonutrients that have benefit in human health (Gupta, Mann, Sood, & Gupta, 2011) . According to (Ocloo, Bansa, Boatin, Adom, & Agbemavor, 2010), jackfruit seeds has 13.50% of protein, 79.34% of total carbohydrate, 2.70% of ash, 1.27% of fat, 22% of starch, 3.19% of dietary fiber and minerals such as calcium, iron, potassium, sodium, copper and manganese. Jackfruit seeds are also rich in phytochemicals such as phenolics, lectin, lignans, isoflavones and saponins which exhibit antioxidant, antifungal, antiaging and anticarcinogenic properties (Swami *et al*., 2012).

The nutritional composition of seeds can be different depending on maturity stage and environment. The presence of these nutrients diversifies the utilization of seeds in most of grown areas. For instance, they could be used as a normal food or functional food without concern of health risk (Swami, Thakor, Haldankar, & Kalse, 2012) and processed into flour by using different treatments such as boiling, roasting and drying (Eke-Ejiofor *et al*., 2014). Moreover, jackfruit seed flour can be mixed with wheat flour for the development of value added food products such as biscuits, cereal bars and breads (Nandkule *et al*., 2015; Santos *et al*., 2011).

Jackfruits are among of rare nutritious fruits found in Tanzania, it is locally cultivated in Zanzibar, Tanga, Morogoro, Mwanza and Bukoba (Mushumbusi, 2015). The Consumption of the pulp/flesh part of the Jackfruit is more popular in Tanzania but utilization of the seeds are still insufficient. Despite the nutrition and related health benefits, in Tanzania the underutilization of the Jackfruits seeds in food system can also be caused by lack of awareness and scarce researched information about the importance of the seeds as one of the food ingredient. In consideration of its health benefit, it is important to find out possible ways through scientific research that can help increasing the utilization of Jackfruits seeds in Tanzania. Due to limited studies in Tanzania that explains the use of Jackfruits, this study intended to shade light on the local processing and its use as well as highlight the scientific benefits of the same. These processing may be adopted by local farmers in order to increase the nutritional value.

Material and methods

Description of the study area and selection of respondents

The present study was conducted in Muheza (5°17´ S, 38°76´ E) and Handeni (4°55´ S, 37°47´ E) districts of Tanga region (Tanzania). Both districts were purposively selected due to their potential in jackfruit production. The qualitative design that involved the semi-structured questionnaire was used to obtain the response from identified respondents on the utilization pattern of jackfruit seeds. Furthermore, the probability sampling procedure was used to obtain the 384 respondents, and the cluster sampling procedure was used to divide the study area according to its division as follows: Muheza district was divided into four clusters (Muheza town, Amani, Bwembwera and Ngomeni) while Handeni district was divided into seven clusters (Kwamsisi, Mazingara, Magamba, Sindeni, Mkumburu, Mzundu and Chanika).

In each division, respondents were randomly selected to participate in the study on size basis. The size was based on the total number of jackfruits growers in respective division.

Afterward, the sample size for the questionnaire was obtained according to Fisher's method: Sample size = $\frac{Z^2 * P(1-P)}{d^2}$

Where: Z = Standard normal variety at 5% = 1.96, P = Expected proportional in population on previous studies or pilot studies (*prevalence*) = 50%, d = Absolute error or precision decided by a researcher 5% = 0.05.

Jack Fruits seeds Sample collection

Ten kilogram of the whole fresh and matured Jackfruit seeds were purchased from the farmers by one day in the study site (each districts five kilogram) then packed in the plastic container and transported for about 6 hours to the laboratory for preparations and further analyses. At the laboratory the sample stored in an open vessels at a room temperature (36.6˚C) for one hour prior preparation.

Preparation of jackfruit seed samples

Preparation of jackfruit seeds involved cleaning and peeling of fresh seeds to remove debris and seed coats. The peeled seeds were soaked in normal bath of water for about 10 minutes and then thin brown spermoderm layer that cover the cotyledons was manually removed. Thereafter, jackfruit seeds were sliced into small pieces, oven-dried at 65°C for 16 hours before grounded into powder by using a blender for 10 minute. The resulted powder was kept in a zipped polyethylene bags and stored at room temperature (24˚C) before used for analyses (Kee & Saw, 2010). In searching for an effective method to reduce anti-nutrients (tannin and typsin inhibitors) present in the seeds, samples were subjected into three treatments (Boiling, roasting and soaking) according to (Eke-Ejiofor *et al.*, 2014) with little modifications.

Treatment 1: Boiling of jackfruit seed samples.

Two kilogram of the sample were placed in a measuring water boiling vessel which setted at boiling temperature of 96°C for 45 minutes and after every 15 minutes the sample was taken out. This was done to check the effect of boiling time on reducing/removing anti-nutritional compound. After boiling process, then the sample was washed with distilled water, lye-peeled and dried at 65°C for 24 hours before grounded into powder for analysis.

Treatment 2: Roasting of jackfruit seed sample.

One kilogram of the sample placed at an Oven were roasted at 160°C for 60 minutes and then removed. After roasting, the sample was washed with distilled water, manual peeled and dried at 65°C in an oven for 24 hours before grounded into powder for analysis.

Treatment 3: Soaking of jackfruit seed sample.

The samples were placed in water for 7 days and then washed, manual peeled and dried at 65°C for 24 hours before grounded into powder for analysis.

Proximate analysis of jackfruit seed samples

Determination of moisture and dry matter contents

Moisture content (% as dry basis) in each sample (Raw, boiled, soaked and roasted) was determined by using the moisture extraction oven (Wagtech convection air laboratory oven). Exactly 5 g of each sample was weighed into a dried moisture dish and placed in the moisture extraction oven at 105°C for 5 hours. Thereafter, the dried samples were cooled in a desiccator and weighed again.

This process was repeated thoroughly until the constant weight was attained. The differences in weight were calculated as the percentage of the original samples (Bradley, 2010). Dry matter content (%) of the seeds was determined by subtracting moisture content (%) from 100%.

$$\text{Moisture content (\%)} = \left(\frac{w1 - w2}{w1}\right) \times 100$$

Where, $w1$ = Weight of the fresh sample (g) and $w2$ = Weight of the dry sample

Determination of ash content

Ash content (%) of samples was determined according to AOAC method as described by (Harris & Marshall, 2017). The carbolite muffle furnace was used to heat the clean empty crucibles at 600°C for 1 hour before cooled in a desiccator, and their weight was recorded as $w1$. Thereafter, 1 g of each sample was placed in the crucible and recorded as $w2$.

Then crucible containing sample was burned in the Carbolite muffle furnace at 550°C for 6 hours. The crucibles were then cooled in the desiccator for 60 minutes and weighed as $w3$.

The percentage ash content was determined according to the following formulae; Ash content (%) $= \left(\frac{w3-w1}{w2}\right) \times 100$.

Determination of crude protein content

Kjeldahl method was used to determine the content of crude protein in samples as described by (Upadhyay & Sahu, 2012)). The applied Kjeltec catalyst was a mixture of 10g potassium sulphate, 1g of copper (II) sulphate and 0.1g of selenium powder. After the introduction of 0.2g of each sample in the digestion flask, 10mL of the concentrated sulphuric acid and Kjeltec catalyst were added followed by digesting the mixture by heating at 420°C for 2 hours. Exactly 10mL of 0.5 sodium hydroxide was added in the 10mL of digested sample to make it basic, while a mixture of 20mL of 4% boric acid and a drop of modified methyl red indicator was used in the process of collecting the produced ammonia gas (as ammonium hydroxide) in the conical flask. Thereafter, the titration was done between the distillate and 0.1 N hydrochloric acid until the endpoint (as pink color) was attained. Finally, the crude protein content (%) was determined by multiplying the percentage nitrogen with 6.25 as a protein conversion factor.

Determination of crude fat content

Crude fat content (%) of the prepared samples was determined soxhlet apparatus (Foss-Soxtec 2055) as described by AOAC (2000), with petroleum ether as extracting solvent. Briefly, fat was extracted by placing 5 g of each sample in the extracting thimble, followed by immersing the thimble inside the extracting can containing 55mL of petroleum ether before boiling at 60°C for 6 hours. Thereafter, the solvent was removed with an aid of a vacuum rotary evaporator at 40°C, followed by the oven-drying of fat at 70°C for 30 minutes. The fat weight was determined by subtracting the weight of an empty flask from the weight of the flask containing dried fat, and the underneath formula was used in the determination of crude fat content (S. Suzanne Nielsen & Carpenter, 2017).: Crude fat content (%) $= \left(\mathrm{w1} - \frac{\mathrm{w2}}{\mathrm{w1}}\right) \times 100$.

Where, $w1$ = Weight of the sample before extraction and $w2$ = Weight of the sample after extraction.

Determination of crude fiber content

The amount of crude fiber (%) in each sample was determined by adopting the AOAC (2003) procedures as described by S Suzanne Nielsen (2010). Briefly, 1 g of each sample was mixed with a mixture of 200mL of 1.25% of sulphuric acid and 0.31 N of sodium hydroxide, and boiled for 30 minutes before washing twice with a solution of ethanol and petroleum ether. The residues obtained were then placed in clean dry weighed crucibles and dried overnight at 100°C inside the moisture extraction oven. Thereafter, the crucibles were heated in a muffle furnace at 600°C for 6 hours, cooled and weighed again. The weight differences of the crucibles were noted as crude fiber and calculated as percentage crude fiber as expressed below: Crude fiber content (%) $= w1 - \frac{w2}{w1} \times 100$

Where, $w1$ = Weight of the sample before heating, $w2$ = Weight of the sample after heating, $w3$ = Weight of the original sample.

Determination of total carbohydrate content

The total carbohydrate content (%) was determined by using the difference method by subtracting the total values for moisture, crude protein, crude fat, crude fiber and ash from 100%.

Determination of mineral contents

One gram of each sample was dried, digested in a 10mL of concentrated nitric acid in a beaker and heated in a hot plate until the solution become clear. Then, the solution was transferred into 100mL volumetric flask and distilled water was added up to the mark. Thereafter, the mineral composition (calcium, potassium, phosphorus, sodium and zinc) was analyzed by Atomic Absorption Spectrophotometric (AAS) methods as per AOAC (EPA, 2007)

Antioxidant activity, phytochemical and anti-nutrient analysis of jackfruit seed samples

Determination of total phenolic content

Total phenolic content of jackfruit seeds powder was determined by Folin Ciocalteu method as described

by (Untalan *et al.*, 2015) with small modification on sample measurement. Briefly, 0.5mL of each extract or gallic acid standard was mixed with 5mL (1:10 v/v diluted with distilled water) of Folin Ciocalteu reagent and 4mL aqueous sodium carbonate. Then, the mixtures were kept in dark for 2 hours. The absorbance of the standard solutions of gallic acid and sample extracts were measured at 765 nm by using UV/Vis spectrophotometer. Total phenolic content was determined from the standard curve of gallic acid and expressed as gallic acid equivalent, GAE (mg/g).

Determination of total flavonoid content

The total flavonoid content of extracts was determined as described by (Untalan *et al.*, 2015). Exactly 0.2mL of extract was added in the flask containing 4mL of distilled water, 0.3mL sodium nitrate. After 5 minutes, 0.3mL of aluminium chloride and 0.2mL of sodium hydroxide solution were added.

The total volumes of the mixture was adjusted to 10mL with distilled water, mixed well and measure the absorbance at 510 nm. The total flavonoid content was determined from the calibration curve of catechin hydrate standard solution and expressed asmg/g of catechin equivalent (CE).

Determination of antioxidant activity

The antioxidant activity of extracts was determined by using 1, 1-diphenyl-2-picryl-hydrazyl (DPPH) reagent as described by (Untalan *et al.*, 2015). An aliquot of 200µl of extract was mixed with 3.8mL of DPPH solution and incubated in the dark at room temperature for 1 hour. The absorbance of the mixture was determined at 517 nm (UV/Vis spectrophotometer) and ascorbic acid was used as a control sample.

Determination of trypsin inhibitors content

The content of trypsin inhibitor of extracts was determined according to ISO 14902:2001 method (STANDARD & ISO, 2001). The trypsin inhibitor was extracted from 1g of the sample at pH 9.5 by adding L-BAPA as substrate. Then the spectrophotometric method was used to measure the quantity of *p*-nitroaniline at 517 nm.

Determination of tannins content

Tannin content of extracts was determined according to ISO 9648 method (Sorghum, 1988). Briefly, 1 g of extracts or standard was weighed into a 50mL beaker followed by 20mL of 50% freshly prepared methanol solution, covered with homogenizer and placed in a water bath at 77 – 80°C for 1 hour. The mixture was filtered and rinsed into a 100mL volumetric flask using 50% methanol. Then, 1mL of the sample extract was homogenized into a 50mL volumetric flask followed by the addition of 20mL of distilled water, 2.5mL of Folin-Ciocalteau reagent and 10mL of sodium carbonate solution (17%).

The mixture thoroughly mixed and allowed to stand for 20 minutes for bluish-green color to develop, and determine its absorbance at 760 nm (UV/Vis spectrophotometer) and concentration based on the standard curve of tannic acid.

Functional properties analysis of jackfruit seed samples

Determination of oil absorption index

Exactly one gram of powdered samples was measured and 6mL (W1) of refined oil was added to the sample and centrifuged at 4000 rpm for 25 minutes. Then, the free oil was decanted and the weight of the centrifuge tube was noted (W2). Thereafter, the oil absorption capacity was calculated as described by AOAC 2001:

$$\text{Oil absorption capacity (\%)} = \left(\frac{w2 - w1}{w}\right) \times 100$$

Where, w = Weight of the raw sample, $w1$ = Weight of the added oil in the sample $w2$ = Weight of the centrifuge tube

Determination of swelling water capacity

Five gram (5g) of sample was placed in a centrifuge tube and the combined weight was recorded. After that, 10mL of distilled water was added in the centrifuge tube and placed in the boiling water at 100°C for 30 minutes. The sample was allowed to cool and centrifuged at 4000 rpm for 20 minutes. Thereafter, the supernatant was poured in a test tube and the weight of the centrifuge tube with swollen

material was recorded. Then, the swelling power was calculated using the following formulae.

$$\text{Swelling power (g/g)} = \left(\frac{w3 - w2}{w1}\right)$$

Where, $w1$ = Weight of the sample (g), $w2$ = Weight of the sample and centrifuge tube (g), $w3$ = Weight of the centrifuge tube with swollen material (g).

Determination of water solubility index

The weight of empty petri dish and raw sample were taken**.** Then, 10mL of supernatant was pipetted into a petri dish and then dried at 105°C in a hot air oven until the constant weight was attained and cooled in a desiccators**.** After that, the weight of petri dish with dry solid was taken. Then, the percentage solubility was calculated by using the following formulae.

$$\text{Solubility (\%)} = \left(\frac{w5 - w4}{w1\ x\ v}\right) \times 100$$

Where, $w4$ = Weight of petri dish (g), $w5$ = Weight of petri dish with dry solid (g), $w1$ = Weight of raw sample (g), and v = Volume of supernatant (mL).

Determination of bulk density index

Bulk density of the each sample was calculated as the ratio of the mass of an untapped powder sample and its volume (Narayana & Narasinga, 1984). The bulk density is expressed in grams per milliliter (g/mL) although the international unit is kilogram per cubic meter (1 g/mL = 1000kg/m^3) because the measurements are made using cylinders.

Statistical analysis

Data from the questionnaire (survey) and laboratory measurements were analyzed with the aid of SPSS statistical package (version 23). All surveyed data of respondents were analyzed by using cross-tabulation based on districts and presented in terms of frequencies and percentages. All laboratory measurements were done in triplicate and expressed as mean value ± standard error of the mean (SEM) and analyzed by using one way analysis of variance (ANOVA). The Duncan's Multiple Range Test (DMRT) was applied to separate mean values at 5%.

Results and discussion

Demographic characteristics of the participants

A total number 384 jackfruit growers from different households at the surveyed area were interviewed in the two selected districts of Tanga region, out of which majority (57.29%) being male. Secondary education was the prevalent education level (77.61%) attained by most respondents in both districts and least number of respondents had no formal education (1.82%). Main occupation claimed by the majority of the respondents was farming (86.46%) since agriculture is the backbone of livelihood in these districts. Please see table 1 below

Table 1. Demographic characteristics of participants in surveyed districts of Tanga region.

Demographic characteristics		Districts		Total	
		Handeni	Muheza	Frequency	Percentage (%)
Gender	Male	109	111	220	57.29
	Female	83	81	164	42.71
Education level	Primary	12	19	31	8.07
	Secondary	151	147	298	77.61
	College	23	12	35	9.11
	University	5	8	13	3.39
	None	1	6	7	1.82
Occupation	Farmers	158	174	332	86.46
	Livestock keeper	19	1	20	5.20
	Employed	5	15	20	5.21
	Others	10	2	12	3.13

Awareness and usage of jackfruit seeds

Most of the respondents (70.05%) across the two districts claimed to use fresh jackfruit seeds (Table 2), with the reason that they have good taste (8.55%), easy to process (0.37%) and majority use just as refreshment (91.08%). With regard to awareness, all respondents claimed to be not aware if jackfruit seeds could be processed into flour and almost all

respondents (99.74%) were also not aware whether the seeds have health benefits (Table 2). Moreover, both boiling and roasting were almost equally preferred by the respondents as preparation methods of jackfruit seeds, with about 29.95% of the respondents had not preferred either method (Table 2). The reasons claimed by the respondents to prefer these methods were good taste of prepared seeds (29.90%), having enough knowledge on preparation method (20.10%), easy processing of seeds (13.30%) and cost effectiveness of the methods (7.00%).

According to the data obtained from surveyed area it seems that most of the people they have litle knowledge about utilization of Jackfruits seeds but they do not have any idea if the seeds have any nutrition benefits and they can use in other form through different processing.

Table 2. Frequencies on usage of fresh seeds, awareness on whether seeds can be used as dry (flour) and their benefits, and preference on selected preparation methods.

Parameters		Districts		Total	
		Handeni	Muheza	Frequency	Percentage (%)
Usage of fresh seeds	Yes	140	129	269	70.05
	No	52	63	115	29.95
Awareness on whether seeds can be used as dry (flour)	Yes	0	0	0	0.00
	No	192	192	384	100.00
Awareness on whether seeds have health benefits	Yes	0	1	1	0.26
	No	192	191	383	99.74
Preference of preparation methods of seeds	Boiling	106	62	168	32.03
	Roasting	81	109	190	38.02
	None	5	21	26	29.95

Proximate composition jackfruit seeds

The amount of moisture was found to be statistically different ($p < 0.05$) among the samples, with the moisture of raw and boiled (for 15 minutes) seed sample been higher (8.86 - 8.93%) than other samples (Table 3). Among the processed samples, lowest value of moisture (5.75%) was found in soaked sample. Changes of moisture contents could be due to interference of seed matrices during processing, drying time and handling of samples before the analysis. The moisture of foods determines its shelf life, hence the lower the moisture content, the longer the shelf life and quality when stored at the ambient temperatures.

Jackfruit seeds are rich source of novel proteins (Ulloa *et al.*, 2017). In this study, protein content varied slightly between the samples and ranged from 11.40 to 12.95% (Table 3). However, in boiled sample there is slightly variation of protein content And It was reported that, crude protein decreased with time due to leaching when seeds are boiled in water (Akinmutimu, 2006). Moreover, no significant difference was observed for raw, soaked, roasted and boiled (for 30 and 45 minutes) samples. Similarly, Eke-Ejiofor *et al.*, 2014 reported similar protein content in roasted, boiled (for 45 minutes) and raw samples. Moreover, the major protein in seeds is jacalin, which reported to possess immunological properties (Gupta *et al.*, 2011). Therefore, processed jackfruit seeds can be regarded as an alternative good source of proteins for the valorization of food products.

Ash content of a food indicates the amount of total minerals present within the food. In this study, ash content of the roasted sample (4.32%) was found to be statistically similar to the raw sample (4.16%) but higher than all boiled and soaked samples (Table 3).

The slight decrease of ash in all boiled and soaked samples could be attributed by the leaching of minerals in the presence of water as reported by Akinmutimu (2006) that, boiling of seeds for 60 minutes lowered ash content than boiled sample for 40 and 20 minutes, hence the presence of water and longer boiling time facilitated nutrient (Prakash, Kumar, Mishra, & Gupta) loss. However, Eke-Ejiofor *et al.*, 2014 reported a significant similarity of ash content in raw, boiled (for 45 minutes) and roasted samples. Thus, roasted sample could be regarded as a good source of ash/minerals in food formulations.

The amount of fat varied significantly between the raw and processed samples and ranged from 0.65 to 1.63% (Table 3). Furthermore, there was no significant difference between all boiled samples and roasting, except for soaked sample which had higher (1.04%) fat content next to raw sample (1.63%). The observed loss of fat could be due to leaching of fatty acids during soaking and boiling, and the influence of heat treatment in boiling and roasting. On contrary while Eke-Ejiofor *et al.* (2014) reported a decrease of fat in roasted sample than boiled (for 45 minutes) and raw sample. However, better processing approaches to minimize the loss of fat in jackfruit seeds need to be investigated. It was reported that, jackfruit seed oils are rich in essential fatty acids with high antioxidant potentials (Nagala *et al.*, 2013). Jackfruit seeds are rich in fibers, in which insoluble fibers are known to be predominant (Mahanta & Kalita, 2015). Current results showed a significant difference in fiber content among the samples with the range from 17.76 to 24.35% (Table 3). The amount of fiber decreased from 24.35% (raw sample) to 22.88% (boiled for 15 minutes), 20.20% (boiled for 30 minutes), 19.29% (soaked), 18.59% (roasted) and 17.56% (boiled for 45 minutes). Similar trend have been reported by Akinmutimi (2006) in which boiled sample for 60 minutes had lower fiber content than other samples. This could be due to moist heat treatment of seeds with longer time, hence more leaching of soluble fibers. Processed seed flour could be incorporated in staple flours and thus increase their prebiotic potentials.

The amount of total carbohydrates varied in different samples and ranged from 43.83 to 70.22% (Table 3). The soaked sample had higher carbohydrate content (70.22%) followed by boiled sample for 15 minutes (61.65%), with raw (44.17%) and boiled sample for 45 minutes (43.83%) been the lowest. On contrary, Eke-Ejiofor *et al.* (2014) reported a significant similarity of carbohydrate content for raw, boiled (for 45 minutes) and roasted samples. Nonetheless, the processed seeds in the present study could still a good source of carbohydrates. Jackfruit seed starch has high swelling and solubility capacity, and can withstand thermal and mechanical shear and hence it is used in food industries as thickener and stabilizer in food products (Mahanta & Kalita, 2015).

Table 3. Proximate composition (%) of processed jackfruit seeds.

Sample of jackfruit seeds	Moisture	Proteins	Fats	Fibers	Ash	Carbohydrates
Raw	8.86±0.06^{d}	12.95±0.07^{ab}	1.63±0.21^{c}	24.35±0.29^{e}	4.16±0.07^{c}	44.17±0.02^{a}
Boiled (15 min)	8.93±0.21^{d}	12.93±0.19^{b}	0.80±0.02^{ab}	22.88±0.66^{d}	3.43±0.09^{a}	61.65±0.78^{d}
Boiled (30 min)	7.69±0.10^{c}	12.32±0.56^{ab}	0.69±0.01^{a}	20.20±0.05^{c}	3.50±0.05^{a}	52.62±0.65^{b}
Boiled (45 min)	7.09±0.04^{bc}	11.40±0.23^{a}	0.68±0.01^{a}	17.56±1.21^{a}	3.46±0.06^{a}	43.83±1.52^{a}
Soaked	5.75±0.09^{a}	12.84±0.06^{ab}	1.04±0.11^{b}	19.29±0.05^{b}	3.93±0.02^{b}	70.22±0.15^{e}
Roasted	6.71±0.27^{b}	11.95±0.87^{ab}	0.65±0.01^{a}	18.59±0.54^{b}	4.32±0.05^{c}	57.79±1.10^{c}

Values are means ± standard deviation of triplicate determinations. Means with same superscript within the same column are not significantly different ($p > 0.05$).

Functional properties of the jackfruit seeds

Analysis of functional attributes of jackfruit seed powder/flour is important as it depicts how the flour will behave when incorporated in food systems (Noor *et al.*, 2014). Results showed that, solubility capacity slightly varied between different jackfruit seed samples and ranged from 0.10 to 0.12% (Table 4). Soaked sample possessed the lowest value (0.10%), while raw, roasted and all boiled samples had statistically similar ($p > 0.05$) solubility capacity. Therefore, flour from the seed soaked in water is not suitable in some food systems such as thickening and stabilization where good solubility is required.

Swelling capacity of samples slightly varied between different jackfruit seed samples and ranged from 2.99 to 3.20 g/g (Table 4). Soaked sample was observed to have a lowest swelling capacity, while the remained samples have significantly similar ($p > 0.05$) values. This could be due to the long duration of soaking in which starch molecules picked enough water and then lost few water molecules during drying, hence few

starch molecules remained to embed other water molecules. Swelling power of jackfruit seed flour is related to starch which was reported to have a high swelling and solubility capacity and thus suitable in food industries as thickener and stabilizer of food products (Mahanta & Kalita, 2015). With respect to bulk density (Table 4), jackfruit seed samples showed minor decrease from 0.76 g/ml (raw sample) to 0.73 g/ml (roasted sample). However, no significant difference was observed in all samples. Bulk density usually depends on how the sample is prepared/treated, handled or stored. Also, Bulk Density represent the behavior of the sample and it is useful parameter that can determine an essential requirement for product packaging and material handling (Juárez-Barrientos *et al.*, 2017). Thus, the employed processing methods had been effective in preserving the native bulk density capacity which makes the seed flour a good fortificant in maize or wheat flour for value added food products.

Oil absorption index indicates the ability of a certain food flour to absorb oil in food systems. For instance, if jackfruit seed flour is to be mixed with wheat flour, it should behave accordingly in term of oil absorption. The present results indicated a slight improvement of oil absorption indices in all processed samples from the raw 4.96 to 4.99mL/g, however not significantly different ($p > 0.05$) in all samples (Table 4). Thus, processing methods very slightly improved the native oil absorption capacity of jackfruit seed flour. It was reported by Mahanta and Kalita (2015) that, a jackfruit seed flour blends well with wheat flour due to its good water and oil absorption capacities.

Table 4. Functional properties of processed jackfruit seeds.

Sample of jackfruit seeds	Solubility index (%)	Swelling index (g/g)	Bulk density (g/ml)	Oil absorption index (ml/g)
Raw	0.12 ± 0.01 ^{b}	3.12 ± 0.10 ^{ab}	0.76 ± 0.01 ^{a}	4.96 ± 0.01 ^{a}
Boiled (15 minutes)	0.11 ± 0.01 ^{ab}	3.19 ± 0.01 ^{b}	0.76 ± 0.01 ^{a}	4.98 ± 0.01 ^{a}
Boiled (30 minutes)	0.12 ± 0.01 ^{b}	3.19 ± 0.01 ^{b}	0.74 ± 0.01 ^{a}	4.98 ± 0.01 ^{a}
Boiled (45 minutes)	0.12 ± 0.01 ^{b}	3.20 ± 0.01 ^{b}	0.75 ± 0.01 ^{a}	4.99 ± 0.01 ^{a}
Soaked	0.10 ± 0.01 ^{a}	2.99 ± 0.01 ^{a}	0.74 ± 0.01 ^{a}	4.99 ± 0.01 ^{a}
Roasted	0.11 ± 0.01 ^{ab}	3.18 ± 0.01 ^{b}	0.73 ± 0.01 ^{a}	4.99 ± 0.01 ^{a}

Values are means ± standard deviation of triplicate determinations. Means with same superscript within the same column are not significantly different ($p > 0.05$).

The present study showed that jackfruit seeds are rich in minerals such as calcium (Ca), sodium (Na), potassium (K), phosphorus (P) and zinc (Zn), hence important for good health. The result showed that, there was a slightly differences between the raw and processed seed samples (Table 5), which could be attributed to mostly leaching of nutrients. However, the seed samples were rich in K (1030–1180mg/100g), then P (380 – 490mg/100g), Ca (210 –270mg/100g), Na (100mg/100g), and least in Zn (1.77– 1.93mg/100g). The mineral values of raw seeds are different from the previously reported values by Akinmutimi (2006), Gupta *et al.* (2011) and Ocloo *et al.* (2010), however the trend of richness from K to Zn is similar with exclusion of P. The observed differences in mineral contents are due to different sources, variety, environment and ripeness of the jackfruit used (Mahanta & Kalita, 2015).

Table 5. Mineral contents (mg/100g) of processed jackfruit seeds.

Sample of jackfruit seeds	Calcium (Ca)	Potassium (K)	Sodium (Na)	Phosphorus (P)	Zinc (Zn)
Raw	220 ^{a}	1170 ^{b}	100 ^{a}	480 ^{c}	1.92 ± 0.69 ^{ab}
Boiled (15 minutes)	230 ^{a}	1120 ^{b}	100 ^{a}	490 ^{c}	1.89 ± 0.15 ^{ab}
Boiled (30 minutes)	210 ^{a}	1150 ^{b}	100 ^{a}	470 ^{bc}	1.93 ± 0.36 ^{b}
Boiled (45 minutes)	210 ^{a}	1170 ^{b}	100 ^{a}	480 ^{c}	1.89 ± 0.52 ^{ab}
Soaked	270 ^{b}	1030 ^{a}	100 ^{a}	380 ^{a}	1.79 ± 0.25 ^{ab}
Roasted	240 ^{ab}	1180 ^{b}	100 ^{a}	420 ^{ab}	1.77 ± 0.17 ^{a}

Values are means ± standard deviation of triplicate determinations. Means with same superscript within the same column are not significantly different ($p > 0.05$).

Phytochemical, ant-nutritional composition and antioxidant activity of jackfruit seeds

The amount of total phenolics varied in different samples and ranged from 0.02 to 0.09% (Table 6). The soaked sample had the second higher phenolic content (0.06%) after the raw sample (0.09%). The lowest amount of phenolics was found in all boiled samples (0.02%). The observed loss of phenolics could be due to leaching of water-soluble phenolic compounds particularly in boiled samples and the instability during heat treatment. According to Maghsoudlou,*et al*, 2019 Heating treatment can affect the attribute to the reaction such as degradation, oxidation or polymerization on the phenolic compound and generating complexes with proteins and carbohydrate.

Flavonoid content of jackfruit seed samples decreased significantly after processing, and thus ranged from 0.52 to 20.09mg/100g (Table 6). All boiled samples had the lowest amount of flavonoid in the range of 0.52 to 1.83mg/100g followed by soaked (4.44%) and roasted (11.82%) samples. The presence of flavonoids in Jackfruits Seeds is an indication benefits due to its antioxidants properties and increased activity of an enzymes that detoxicity carcinogens (Sreeja Devi, Kumar, & Sabu, 2021). Similar to phenolics, leaching of nutrients in water could be accelerated by heat treatment and less influenced by heat alone.

Jackfruit seeds are known for their significant antioxidant capacity, mostly due to phytonutrients such as phenolics, flavonoids, saponins, and essential fatty acids (Nagala *et al.*, 2013; Swami *et al.*, 2012). The results showed the substantial decrease of antioxidant activity of raw seed sample during processing, with the range from 1.18 to 12.00% (Table 6). Boiled sample for 45 minutes, soaked and roasted sample had significantly lower radical scavenging activity than the rest samples. This could be due to the loss of antioxidants as a result of leaching of nutrients and destruction by heat and according to (Sreeja Devi *et al.*, 2021) the antioxidant activity can be well preserved through storage at lower temperature.

Raw jackfruit seeds contain a number of anti-nutrients such as tannins, oxalates, phytates and trypsin inhibitors. Anti-nutrients interfere the digestibility and absorption of important nutrients, hence need to be reduced/removed from the diets (Mahanta & Kalita, 2015; Swami *et al.*, 2012). The present findings showed a 50% decrease in tannin during processing, with the range from 0.01 to 0.02% (Table 6). Thus, the employed treatments were not enough to completely destroy tannins in seeds. Moreover, roasting and boiling of seeds for 30 and 45 minutes reduced tannins by at least 50% than the other treatments. However, according to (Abiola, 2018), tannins have some thermostability and thus less affected by heat processing.

On the other hand, trypsin inhibitors had decreased significantly in both boiled samples for 30 (0.73%) and 45 (0.02%) minutes, followed by the roasted sample (9.12%). Akinmutimi (2006) also reported that, boiling the seeds for 60 minutes completely removed trypsin inhibitors. Contrary to tannins, combination of long time and boiling can completely destroy trypsin inhibitors (Akanji *et al.*, 2003; Mahanta & Kalita, 2015). Therefore, protein indigestibility related-problems such as pancreatic hypertrophy due to trypsin inhibitors cannot occur after using processed seeds which were boiled for at least more than 45 minutes.

Table 6. Phytochemical, anti-nutritional composition and antioxidant activity of processed jackfruit seeds.

Sample of jackfruit seeds	Flavonoid content (mg/100g)	Phenolic content (%)	Antioxidant activity (%)	Tannin content (%)	Trypsin inhibitors content (%)
Raw	20.09 ± 0.44 ^{e}	0.09 ± 0.01 ^{d}	12.00 ± 0.79 ^{c}	0.02 ± 0.01 ^{a}	18.35±0.44 ^{d}
Boiled (15 minutes)	1.83 ± 0.04 ^{ab}	0.02 ± 0.01 ^{a}	2.37 ± 0.01 ^{b}	0.02 ± 0.01 ^{a}	16.00±0.67 ^{c}
Boiled (30 minutes)	0.52 ± 0.01 ^{a}	0.02 ± 0.01 ^{a}	2.01 ± 0.01 ^{b}	0.01 ± 0.01 ^{a}	0.73 ± 0.08 ^{a}
Boiled (45 minutes)	0.52 ± 0.01 ^{a}	0.02 ± 0.01 ^{a}	1.36 ± 0.01 ^{ab}	0.01 ± 0.01 ^{a}	0.02 ± 0.01 ^{a}
Soaked	4.44 ± 0.43 ^{c}	0.06 ± 0.01 ^{c}	1.19 ± 0.10 ^{a}	0.02 ± 0.01 ^{a}	18.78±0.24 ^{d}
Roasted	11.82 ± 0.87 ^{d}	0.03 ± 0.01 ^{b}	1.18 ± 0.01 ^{a}	0.01 ± 0.01 ^{a}	9.12 ± 0.06 ^{b}

Values are means ± standard deviation of triplicate determinations. Means with same superscript within the same column are not significantly different ($p > 0.05$).

Conclusion

Jackfruit seeds present a low-cost, widely available and highly nutritious alternative food source. Yet there is a huge underutilization of seeds in the country due to the lack of awareness on their importance in improving health and lack of processing knowledge as data explained from surveyed area. The present study showed that, processing of jackfruit seeds maintained the native functional properties, reduced some of the nutrients and phytochemicals, and more importantly reduced tannins and trypsin inhibitors, hence reduces the risk of indigestibility and malabsorption of useful nutrients in the body. It can be concluded that, no one processing method was found to be the best in all aspects analyzed in this study. However, with the exception of antioxidant activity, boiling the seeds for 30 to 45 minutes could provide an optimal amount of nutrients and functional properties, and less anti-nutrients, hence the resulting seed flour could be used in food industries as fortificant in maize and wheat flours, and as thickener or stabilizer (extracted starch) of food products.

Data availability

Reader can access data that support the conclusion of this study in submitted research paper.

Conflicts of interest

There is no any conflict of interest on this research paper.

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