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Effect of various Processing Methods on Jack Fruit (*Artocarpus heterophyllus*) Seed Flours

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ABSTRACT: Jackfruit seeds are underutilized and obscure with high potential for use in various food applications. This study aimed to evaluate the outturn of various processing methods on the composition, physical and antinutritional factors of seed flour from jackfruit. Seeds are subjected to roasting (180°C/15 minutes), boiling (100°C/60 minutes), steaming (121°C until softened), parching (200°C/30 minutes) and lye peeling (80°C/15 minutes in 0.05% NaOH). After processing the seeds were sliced and dried at 50°C. The moisture content varied from 4.36% to 6.92%. The protein content increased in thermally treated flours and was highest in RJFSF (Roasted) at 16.61%. Carr's Index and Hausner Ratio varied between 11.80 – 15.57 and 1.13 – 1.18 showing good flow ability in all the flours. Thermally treated flours recorded a decrease in tannin and phytic acid content compared to raw JFSF. Thermal processing methods were more effective in improving composition, possess physical properties that can be applied in wet processing and reduced anti-nutritional factor in the JF seed flours, thus, suggesting that these seed flours can be incorporated/substituted/ replaced into different foods.

Keywords: Jackfruit seeds, antinutrients, roasting, physical properties.

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus*) belongs to the Moraceae family, highly produced and consumed in Southeast Asia and Brazil (Lima *et al.*, 2014). Jackfruit contains about 100 to 500 seeds, each seed measures 2 to 4 cm long and represents18–25% of the total fruit weight (Kumoro *et al.*, 2020). On average, these seeds possess a 2–4 cm length and a diameter of1–2 cm. Even though is poorly digested in human digestive tracts, consumption for culinary purposes (boiled or roasted) is noted(Zhang *et al.*, 2017). Strikingly, these are rich in starch (60–80%), and other nutrients(Anaya-Esparza *et al.*, 2018). The flour from seedsholds73.87 g/100 g of carbs 31 g/100 g of dietary fibre, 14 g/100 g protein and 1g of fat(Trejo Rodríguez *et al.*, 2021). Seed is comprised of phenolic acids, flavonoids, and stilbenes (Shanooba *et al.*, 2020). Despite having a wide range of benefits, these seeds are not fully exploited and are less recognized by people (Butool and Butool 2015). Apart from having nutritional benefits they also have many physiological benefits (Waghmare *et al.*, 2019).

Fresh seeds have a shorter shelf life; these are traditionally munched after boiling, steaming and roasting. As harvested seeds are incapable to stored as such, flour can be a possible substitute to increase the storage life. Further, when it is ingested, it results in digestive due to antinutritional factors (ANF) such as tannin and phenols. By reducing the level of ANF in these seeds, a higher-value product can be developed. These can be minimized or destroyed by thermal processing (Abiola *et al.*, 2018). These methods are highly used for the inactivation of toxic composites, inhibiting enzymes, texture improvement and elevating palatability increasing nutrient availability (Sandhu *et al.*, 2015).

The seed flour jackfruit can be investigated as a prospective alternative as replacement or substitution along with conventional flour formulations in the case of confections, extrudates, bakery items, or as a hydrocolloid (coagulating and stabilizing additive). It can also be utilized as protein and carbohydrate augmentation (Maduwage *et al.*, 2019). Hence, investigate the properties for effective practical application of jackfruit seed flour in foods. Therefore, attempts were geared up with an objective to (1) process the jackfruit seeds into flour by applying thermal treatments (boiling, steaming, roasting, parching and lye peeling) and (2) investigate the outcome of thermal treatments on properties and antinutritional factors on flours from jackfruit.

MATERIALS AND METHODS

Plant material: Jackfruit seeds from fully ripened fruits were procured from Kerala, India.

Processing methods: To remove extraneous matters jackfruit seeds were manually cleaned to remove and they were steeped overnight in water so that removal of the thin whitish membrane (aril) on the seeds would be easy (Dasaesamoh and Seechamnanturakit 2014). Seeds were dried to remove surface moisture at 50°C for 3h. The process of roasting was carried out at 180°C and 200^{0}C for 15 minutes where180°C temperature was optimized for roasting as high temperatures are leading to charring of the outer surface of the JF seeds. Boiling conditions were optimized for JF seeds by boiling in an open pan for 15, 30, 45, 60 and 75 mins at 100°C. Seeds boiled for 75 mins became very soft and mushy. Peel removal was easy when boiling was done for 60 minutes when compared to 15, 30, 45 minutes. So, 60 minutes at 100°C was taken into consideration for boiling of JF seeds. The water (w/v): sample ratio is maintained at 5:1. Seeds are steamed at 121°C till soft and cooked.

The steaming method was executed following the experiment of Ezim *et al.* (2020) by minute alternations. Initially, fine sand was preheated to 200°C which took around 1-2 minutes on an induction stove, then JF seeds without aril portion were mixed in the sand and roasted at 200°C for 30 minutes by constant stirring. Lye peeling was accomplished method of Eke-Ejiofor *et al.* (2014) with slight variation. Dipping raw seeds after removal of aril at 80°C and 100°C solutions of 0.05% sodium hydroxide for 15 minutes. 80°C for 15 minutes was the optimum time and temperature combination for lye peeling.

After boiling and steaming the brown spermoderm layer was removed. In the case of parching and roasting the fleshy white cotyledons were obtained by scraping the brown spermoderm layer with a knife. After dipping in lye solution seeds were washed and then removal of the brown outer layer was discarded. Fleshy white JF seeds cotyledons obtained from various treatments were chopped into thin slices and dried in a hot air oven (50^{o}C) separately till constant weights were achieved.

Pulverizing and storage: Dried seed slices of all the treatments were pulverized and sieved using a 250 -mesh sieve to obtain uniform flours (Mukprasirt & Sajjaanantakul 2004; Kushwaha *et al.*, 2020) separately. The flours were reserved in labeled airtight containers at ambient conditions before making use of them for analysis. The yield of the flours obtained from roasting, boiling, steaming, parching and lye peeling was 55.63%, 53.86%, 53.12%, 54.63% and 52.16% respectively.

Proximate analysis: Protein estimation was done by using Kjeldahl Apparatus (Kjeltron, 4 tests, Tulin Equipments, Chennai, India) with a 6.25 conversion factor for nitrogen. Fat percent was evaluated by using Soxhlet Apparatus (Soxtron, V- 220v, Size – 2 tests, Temp – 150°C). Muffle Furnace (Hasthas, Temp – 900°C) was exercisedto determine the ash contents. Crude Fibre was estimated using Fibre Analysis System (FibroTRON, Tulin Equipments, Chennai, India). The oven method was explored to find the moisture content. 100% differential calculation is made to obtain carbohydrate content.

Physical properties

Bulk and Tapped Density. The bulk densities of the flours were calculated by following the formula and method described by Okakaand Potter (1979). Tapped density was determined by weighing after tapping the contents.

$$\frac{\text{Bulk}}{\text{Tapped}}\ \text{density} = \frac{\text{Weight (g)}}{\text{Volume (cm}^3)} \quad (1)$$

Carr compressibility index and Hausner ratio: The flow characteristics of the flour samples were measured by calculating Carr Index (Carr, 1965) and Hausner ratio (Hausner, 1967) from bulk density and tapped density values.

$$\text{Carr Index CI} = \frac{\text{Tapped density - Bulk density}}{\text{Tapped density}} \times 100 \quad (2)$$

$$\text{Hausner Ratio} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad (3)$$

Antinutritional Factors (ANF)

Determination of tannin: Tannic acid experiment was taken from the work by Azeez *et al.* (2015) earlier proposed by Makkar (2003), with some corrections. 0.2g sample steeped in 25 ml of acetone (70%) in a beaker and kept in iced water bath (20 mins). Low temperature was maintained to keep the samples to avoid the degradation of tannins. The contents of the beaker were centrifuged approximately 3000 rpm for 10 min. Whatman No. 1 filter paper is used to filter the concentration, made up with distilled water (0.5 ml) and add 500 µl of Folin-Ciocalteau reagent. 1.5 ml of Na_2CO_3 and 0.5 mL of distilled water to the mixture. Vertexing followed by incubation for 40 mins at room temperature. Absorbance was read against blank at 725 nm for sample and tannin standards. % Tannic acid was recorded.

Determination of phytic acid: Latta and Erskin (1980) technique was implied for phytic acid. Dried sample (0.2g) placed in conical flask (250 mL). The extraction of sample in 2.4% 25 ml HCl was done and shaked in orbital shaker for 1 hr at ambient conditions. Centrifugation was carried out at 3000 rpm for 30 mins. For the phytate analysis 3 ml of supernatant was transferred into test tube. To the test tube of Wade reagent(1mL) (0.03% solution of $FeCl_6H_2O$ containing 0.3% sulfosalicylic acid in water) and vortexed (1 min). Absorbance was recorded at 500 nm and phytate was quantified using standard calibration curve of phytic acid (2 to 10 mg/ml). Result was expressed as phytic acid, g/100 g.

Statistical analysis: All the data were statistically evaluated by one way analysis of variance (ANOVA) and the significance of differences between means were determined by Duncan's multiple comparison test at a 5% significance level ($P < 0.05$) by using IBM SPSS statistics software, version 20.0 (IBM, SPSS, Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Proximate analysis: The composition of untreated and thermally processed JFSFs were analyzed and projected in Table 1. MC of JFSFs ranged from 4.36±0.18% to 6.92±0.04%. Highest MC was seen in BJFSF (6.92±0.04%) followed by SJFSF (6.54±0.13%) and least was recorded in RJFSF (4.36±0.18%).

Table 1: Proximate composition of JFSFs on dry basis.

	Moisture (%)	Ash (%)	Fat (%)	Crude Fibre(%)	Protein (%)	*Carbohydrate (%)
Untreated JFSF	5.41±0.22^{d}	2.55±0.00^{d}	0.69±0.02^{a}	3.48±0.07^{a}	15.37±0.08^{d}	72.49±0.17^{b}
RJFSF	4.36 ±0.18^{e}	2.69±0.01^{a}	0.29±0.01^{d}	2.88±0.10^{c}	16.61±0.13^{a}	73.16±0.02^{a}
BJFSF	6.92±0.04^{a}	2.43±0.00^{e}	0.47±0.02^{c}	3.47±0.06^{a}	15.86±0.11^{c}	70.82±0.19^{d}
SJFSF	6.54±0.13^{b}	2.35±0.00^{f}	0.59±0.03^{b}	3.47±0.09^{a}	15.83±0.09^{c}	71.19±0.30^{d}
PJFSF	4.45±0.06^{e}	2.62±0.00^{c}	0.32±0.03^{d}	2.94±0.04^{c}	16.32±0.09^{d}	73.32±0.20^{a}
LPJFSF	6.03±0.20^{c}	2.65±0.00^{b}	0.62±0.03^{b}	3.29±0.26^{b}	15.46±0.09^{d}	71.93±0.30^{c}

Note: Values are expressed as mean ± SD (n = 3). The values in the same column with different superscript letters are significantly different ($p < 0.05$) as per Ducan's multiple comparison test. JFSF – Jack Fruit Seed Flour, R – Roasted, B – Boiled, S- Steamed, P- Parched and LP – Lye Peeling. *Carbohydrates content was calculated based on the percent differential from 100%

Reduced moisture content in flours achieves better shelf life and stability. This study's MC values were following the investigation made by Eke-Ejiofor *et al.* (2014), which varied between 3.2% to 6.6% in various jackfruit seed flours. Kushwaha *et al.* (2020) mentioned higher values (5.78%–8.48%) of MC compared to us in JFS. Similar range of moisture content values were observed by Kirthy Reddy *et al.*, 2017 in date seed flour also. MC values are significantly different ($p < 0.05$) as per the Duncan multiple comparison test except for RJFSF and PJFSF where notable differences were not seen.

JFSFs ash content values aligned between 2.35±0.00% – 2.69±0.01%. Same was observed Ocloo *et al.* (2010) study in JFSF. The values given by Eke-Ejiofor *et al.* (2014); Noor Fadilah *et al.* (2021) were 2.46%–2.76% and 2.43% - 2.75% accordingly in treated JFSFs, these were in distinguish able with the present study. These values were significantly different ($p < 0.05$, Duncan test) for all samples in the study. Kushwaha *et al.* (2020) study claimed an ash content of 3.33% in matured JFSF which was higher than our study.

Fat content values ranged from 0.29±0.01% in RJFSF to 0.69±0.02% in untreated JFSF and showed non-significant difference ($p < 0.05$) between SJFSF and LPJFSF, RJFSF and PJFSF. This result might be due to leaching of fat during heating in all the samples except for untreated flour. The information was in accordance to Ijeh *et al.* (2010) where fat content reduced during boiling and roasting of African breadfruit seeds. Kushwaha *et al.* (2020) also proclaimed the fat content ranged from 0.58% to 0.73% in JFSFs of various maturity levels. Our results were correlating well with Noor Fadilah *et al.* (2021) study fat content of 0.56% and 0.22% in raw and thermally treated jackfruit seeds.

Crude Fibre content in JFSF samples ranged from 2.88±0.10% to 3.48±0.07% and significantly differed ($p < 0.05$). Highest content is observed in untreated JFSF and lowest in RJFSF. Identical results to our study were mentioned by Eke-Ejiofor *et al.* (2014) in jackfruit seed flours (2.43% to 6.17%) with raw JFSF having the lowest value

Protein content in JFSFs significantly differed ($p < 0.05$) where the values assorted from 15.37±0.08% (Untreated JFSF) to 16.61±0.09% (RJFSF). This trend could be resulted due to reduction in antinutrients and increased availability of protein during thermal processing. Close values were mentioned in research by Eke-Ejiofor *et al.* (2014) where untreated JFSF showed lower protein value (12.45%) and highest value was recorded in roasted jackfruit seed flour (16.80%). But our results are quite contradictory to the values were mentioned in research by Ezim *et al.* (2020) where untreated JFSF showed higher protein value (15.88%) and lowest in boiled jackfruit seed flour (9.9%). Noor Fadilah *et al.*, (2021) mentioned 14.07% protein content in jackfruit seeds.

Carbohydrate values in this study are ranging from 70.82±0.19 in BJFSF to 73.32±0.20 in PJFSF having significant difference ($p < 0.05$). The above values are matching with the Trejo Rodriguez *et al.* (2021) jackfruit seed study (73.87%). Study by Eke-Ejiofor *et al.* (2014) mentioned CHO values between 70.76% - 79.02% in untreated and JFSFs obtained after treatments.

Physical Properties. Statistical values of physical properties are presented in Table 2.

Bulk Density (BD) and Tapped Density (TD). It was perceived that the superior values of tapped density than the bulk density was visioned in all flours, as the volume of voids spaces become insignificant by application of external force (Smita *et al.*, 2019). Density measures powders heaviness. It decides requirement for packaging, handling materials in the food industry (Ocloo *et al.*, 2010). Significant difference ($p < 0.05$) was noted among BJFSF and SJFSF. BD values fluctuated from 0.73±0.00g/ml in RJFSF to 0.82±0.01g/ml in BJFSF and tapped density values were highest for BJFSF (0.926g/ml) and least was recorded in RJFSF (0.827g/ml). The current findings were alike to the values reported by Kushwaha *et al.* (2020) in JFSFs. Ejiofor *et al.* (2014) reported similar findings that roasted jackfruit seed flour has lower bulk density value when compared with other heat treated and untreated seed flours (Kirthy Reddy *et al.*, 2018). In study performed by Batariuc *et al.* (2021) showed that the dry heat treatments noted least bulk density values in sorghum flours.TD of samples manifested significant difference ($p < 0.05$). Thermochemical degradation of vaporous compounds diminishes the mass ratio over the sample volume is the cause for decreased density as explained by Ribeiro *et al.* (2020).

Table 2: Physical properties of JFSFs.

	Untreated JFSF	RJFSF	BJFSF	SJFSF	PJFSF	LPJFSF
Bulk density	0.73±0.01[c]	0.73±0.00[c]	0.82±0.01[a]	0.78±0.02[b]	0.74±0.00[c]	0.75±0.00[c]
Tapped density	0.85±0.00[c]	0.82±0.00[d]	0.92±0.00[a]	0.90±0.10[b]	0.86±0.00[c]	0.85±0.00[c]
Carr's Index	13.27±0.15[b]	11.85±0.80[d]	11.83±0.95[a]	13.00±1.23[b]	15.59±0.66[c]	13.26±0.23[c]
Hausner Ratio	1.15±0.03[ab]	1.13±0.01[b]	1.13±0.01[b]	1.15±0.01[b]	1.18±0.01[a]	1.15±0.00[ab]

Values are expressed as mean ± standard deviation (SD). The mean values with different superscript letters in the same column are significantly different ($p < 0.05$) as per Duncan multiple comparison test. Values are means of triplicate determinations. JFSF – Jack Fruit Seed Flour, R – Roasted, B – Boiled, S- Steamed, P- Parched and LP – Lye Peeling.

CI and HR: The HR and CI are an indirect measurement of powder or particle flow property cohesive in the sample is more if HR and CI are high. (Olawoye and Gbadamos 2020). This is an excellent measure indicating the compactness mechanism during processing. CI is a commonly adopted measure for flowability in flours. Having low CI below 25 indicates a superior flowability (Jadhav *et al.*, 2017). In our study CI values ranged from 11.83±0.95 (BJFSF) to 15.59±0.06 (PJFSF) having significant different ($p < 0.05$). The values obtained in our study agree with results of Leite *et al.* (2020) in cocoa powder. Dadi *et al.* (2019) reported that as temperature increased CI and HR also increased. HR values ranged from 1.13±0.01 (BJFSF) to 1.18±0.01 (PJFSF), HR lower than 1.25 indicates a good flowability (Jadhav *et al.*, 2017). In this work significant difference ($p < 0.05$) was noted among JFSFs for HR.

Anti-nutritional Factors

Tannins and Phytic acid: This work's findings confirmed that a trace amount of ANF (tannin) was present in the Untreated JFSF (0.244g/100g) manifested in Fig. 1 with significant differences ($p < 0.05$) with other JFSFs. This level is higher than those reported (0.01%) in Eyoh G.D (2020) and lower than those mentioned (0.04%) in Noor Fadilah *et al.* (2021) decrease in the tannin content value (0.01) was seen in all thermally treated JFSFs samples. The highest reduction of tannin content was seen in PJFSFs (0.011± 0.11). Tannin as described by Sharma *et al.* (2019) is a polyphenol present in plants. It is highly water-soluble and could effort easily drain during moist thermal processing into the liquid medium. Ndyomugyenyi *et al.* (2014) found that 84% of tannins were removed in jackfruit beans following roasting.

The amount of phytic acid in untreated JFSF was 0.084g/100g followed by 0.066g/100g (LPJFSF) and all thermally processed flours have a greater decrease in the phytic acid content which is presented in Fig 1. Least was recorded in RJFSF (0.014g/100g). All flours were significantly different from untreated JFSF ($p < 0.05$). Our results are identical to that of Noor Fadilah *et al.*, (2021) who projected roasted jackfruit seed sample gave the lowest reading which is 0.0159 g/100g among all treatments. Due to formation of insoluble complexes between phytate and other components this may partly leached into cooking medium or heat deteriorated. For both tannin content and phytic acid significant difference was manifested between untreated and LPJFSF samples.

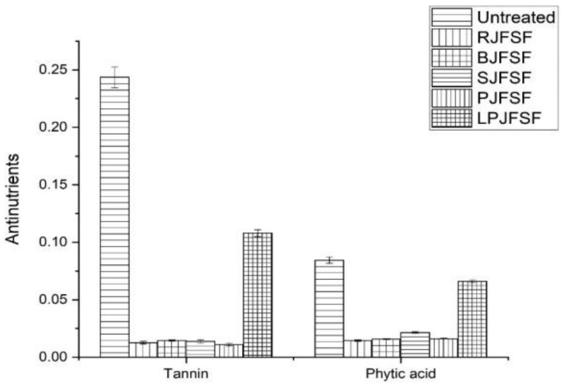

Fig. 1. Antinutritional Factor in JFSFs (Tannin and Phytic Acid).

CONCLUSIONS

This study has evaluated the compositional, physical, functional properties and antinutritional factors of flours obtained from Jackfruits seeds by various processing methods like roasting (180 °C/15 minutes), boiling (100 °C/60 minutes), steaming (121°C until softened), parching (200 °C/30 minutes) and lye peeling (80°C/15 minutes in 0.05% NaOH). The flours obtained from each processing method along with untreated flour were analyzed. Protein content in JFSFs significantly differed ($p < 0.05$) where the values ranged from 15.37±0.08% (Untreated JFSF) to 16.61±0.09% (RJFSF) having potential application as plant protein. Carr's Index and Hausner Ratio values for all flours indicated superior flowability. Thermally processed flours recorded reduction of ANFs. This study disclosed that JFSFs can be budding ingredient in the development of new food formulations. Further, processing of seeds into flours by various processing methods minimizes waste disposal problems.

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Conflict of Interest. None.

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