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RESEARCH ARTICLE

CHARACTERIZATION OF PHYSICO-FUNCTIONAL, NUTRITIONAL, AND ANTIOXIDANT PROPERTIES OF JACKFRUIT BY-PRODUCT FLOUR AND ASSESS ITS POTENTIAL USE IN THE DEVELOPMENT OF PASTA

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ABSTRACT

Jackfruit (*Artocarpus heterophyllus* L.) is a popular seasonally grown crop in Sri Lanka. The by-products generated from jackfruit season are mostly used as animal feed or landfilled without being used. Therefore, this research aimed to characterize the nutritional and functional properties of jackfruit by-product flour (jackfruit core and rags; 3:1 w/w) while exploring its potential use to develop pasta. The physico-functional properties, proximate composition, and antioxidant properties of jackfruit by-product flour compared with commercial wheat flour were analyzed. Composite flour was prepared by substituting wheat flour with different amounts of jackfruit by-product flour (25%, 35%, and 40% w/w). Thirty semi-trained panelists were used to conduct a sensory evaluation to select the best pasta made from a composite flour mixture. Proximate composition, physical properties, and shelf-life of the selected best product were analyzed using standard methods; in comparison to wheat flour, jackfruit by-product flour displayed a higher water absorption capacity (8.77±0.06%) and swelling capacity (46.00±5.66 mL), indicating that it can be used for making bakery products with enhanced properties. The jackfruit by-product flour contained a significantly ($p<0.05$) high amount of crude fiber (13.00±1.13%) compared to the wheat flour (2.24±0.23%). Further, the total phenolic and flavonoid content of jackfruit by-product flour were 40.9±0.02 mg GAE (Gallic acid equivalent)/100 g and 65.7±0.02 mg QE (Quercetin equivalent)/100 g, respectively, and it showed 8.46 ± 0.01 mg TE (Trolox equivalent)/100 g DPPH radical scavenging activity. The pasta made from 25% (w/w) jackfruit by-product flour showed the highest mean rank values for all the tested sensory attributes. The shelf-life study showed that the developed product could be stored in low-density polyethylene laminated packages for 6 weeks under ambient temperature. In conclusion, jackfruit by-product flour can be used as a partial replacement for wheat flour when preparing pasta.

Keywords: crude fiber, Jackfruit by-product flour, pasta, sensory analysis, shelf-life analysis, and water absorption capacity

INTRODUCTION

The jackfruit (*Artocarpus heterophyllus* L.) is the most popular type of tropical fruit-bearing trees grown in many parts of Southeast Asia (Rahman, 1999). India and Bangladesh are the world's largest jackfruit-producing countries, with annual production of 1.4 million tons and 926 tons of jackfruit, respectively. In Sri Lanka, October to December and March to May are the fruit-bearing seasons of the jackfruit crop. The jackfruit tree can produce a higher yield, which is 70-200 kg of fruits per tree, which is higher than the yield of any other trees in the family of Moraceae, and approximately 5080 tons of fruits are produced per hectare each year (Akter and Haque, 2019).

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Mature jackfruit comprises the outer peel, central core, seeds, rind, and bulbs. Bulbs and seeds are the most popular edible parts among people, while outer peels, cores, and rags are considered waste products, which consist of about 60% (w/w) of the total weight of the fruit. The rind is the jackfruit peel, which is green in color and fibrous, and it is the outer protective layer. It contains 27.75% of cellulose, 7.52% of pectin, 6.27% of protein, and 4% of starch (Sundarraj *et al*., 2017). The jackfruit rags separated the bulbs into compartments (Dam *et al*., 2013), and they have a rubbery structure. The jackfruit seeds and the fleshy parts are consumed in boiled form and as curries in many countries.

In Sri Lanka, jackfruit waste products or by-products are mostly used as animal feed, even though they are rich sources of carbohydrates, crude protein, crude fibre, bio-actives, and minerals such as calcium and phosphorus (Ranasinghe *et al*., 2019). There is a huge potential for use for these jackfruit by-products after drying, freezing, canning, or converting them into value-added products. For instance, there is some evidence of the development of different food products from jackfruit by-products, including jams, jellies, marmalades, and ice creams in several countries (Jagadeesh *et al*., 2006; Ranasinghe *et al*., 2019). Jackfruit by-products are a great source of pectin, and scientists have extracted pectin using organic and mineral acids, which are used to make jam and jelly products (Xu *et al*., 2018). However, the extracted pectin from the jackfruit by-product is poor in solubility and contains a high ash amount compared to the commercially available pectin.

The production of composite flour incorporating jackfruit by-products would be one of the best solutions to increase the utilization of these by-products and thereby reduce the disposal of valuable nutrients. Further, the incorporation of jackfruit by-products can increase the fibre content of the composite flour mixture. The products with high fibre content have been proven to be beneficial for human health by reducing effects on colonic cancer and constipation, helping to maintain bowel movement, and lowering blood pressure (Guillon, 2000; Galisteo, 2008; Ysuf *et al*., 2022). During the jackfruit season, considerable amounts of by-products are generated, and it can be effectively used to develop some value-added products with advanced technologies to better exploit this valuable food source. Around 60-70% (w/w) of jackfruit consists of by-products such as outer rind, central core, and rags. Currently, there is a lack of fiber-rich, value-added products available in the local market. Therefore, the development of fibre-rich food products is in great demand, and it may surely boost the health benefits to minimize some common health issues arising in all age groups in the world. Accordingly, this research aimed to investigate the possibility of the production of value-added pasta using jackfruit by-product flour while the characterization of physico-functional properties of jackfruit by-product flour.

MATERIALS AND METHODS

Sample collection

Medium size mature jack fruits (*Artocarpus heterophyllus* L.*)* without any outside physical damage were randomly collected from home gardens in Kamburupitiya (Latitude: 6.0779° N, Longitude: 80.5633° E), Matara, Sri Lanka. Fruits were washed with tap water before further processing.

Preparation of flour samples

The outer peel (rind) of jackfruit was removed and carefully cut using a clean stainless-steel knife. The central core and rags were separated and cleaned with water, and the excess water was drained using a clean muslin cloth. The initial fresh weight of the central core and rags was recorded. The central core was sliced into thin pieces (5 mm) and soaked in a 5% (v/v) citric acid solution for 10 minutes. Afterward, the sliced core and rags were placed on dryer trays in a dehydrator and dried for 9 hours at a temperature of 57±2 °C. Once completely dehydrated (less than 5% moisture content), the rags and central core were ground into a fine powder and sieved using a 250 µm sieve. The resulting flour was then packed into Low-Density Polyethylene (LDPE, 63.5 µm) packages and stored at room temperature (30±2 °C) until further use.

Determine the physico-functional properties of jackfruit by-product flour and wheat flour

Bulk density

The bulk densities of jackfruit by-product flour and wheat flour were determined using the methods described by Anosike *et al.* (2023). Briefly, 50 g of flour samples were weighed and transferred into a graduated measuring cylinder. The volume occupied by each flour sample was recorded, and the bulk density was calculated as the volume (mL) per sample unit weight.

Water and oil absorption capacities

Water and oil absorption capacities were determined using the centrifuge method described by Sosulki (1976). Sample (1 g) was mixed with 10 mL distilled water or coconut oil and allowed to stand at ambient temperature (30±2 °C) for 30 min. The mixture was centrifuged for 30 min at 3000 rpm and decanted the water/oil. After centrifugation, water/oil absorption by flour was calculated by subtracting the original sample weight from its final weight. Water and oil absorption capacities were measured in grams of water/oil bound per gram of flour.

Swelling capacity

The swelling capacities of flour were determined using the method described by Anosike *et al.,* (2023). The flour was filled into a graduated cylinder (100 mL) up to the 10 mL mark, and distilled water was added to give a total volume of 50 mL. The cylinder with the sample was inverted for 2 min, and the suspension was again inverted and kept for 8 min. The volume occupied by the sample was recorded after the 8th min.

Gelatinization temperature

The gelatinization temperatures of the samples were estimated using the method described by Chandra and Samsher (2013). The flour sample (2 g) was weighed accurately and transferred into 20 mL screw-capped tubes. The amount of 10 mL of water was added to the sample and heated slowly in a water bath until it formed a solid gel. The respective temperature was measured at the end of the complete gel formation and recorded as a gelatinization temperature.

Colour measurements

The colour of the samples was measured using a colorimeter (BCM 200, China), and the CIE L*, a*, and b* colour parameters were recorded in each flour sample.

Determination of Proximate Composition

Moisture content (MC), crude protein (CP), crude fat (CF), crude fiber (CFb), and ash contents of jackfruit by-product flour and wheat flour were determined using the AOAC 934.01, 984.13, 920.39, 962.09 and 942.05, respectively (AOAC, 2006). Total carbohydrate content was calculated using a different method (FAO, 2003).

Determination of Antioxidant Properties

The total polyphenol, flavonoid, and DPPH radical scavenging activity of jackfruit by-product flour was determined.

The method used by Fernando *et al.*, (2021) was adopted with some modifications to determine the total polyphenol content. Briefly, 400 µL of jackfruit by-product flour extract in water was mixed with ten times diluted Folin-Ciocalteu reagent (FCR) followed by adding 7.5% (w/v) Sodium bicarbonate. Then, the mixture was diluted up to 10 mL and kept dark for 120 min. The absorbance was measured at 760 nm, and the result showed as mg of Gallic acid equivalents (GAE) per 100 g of the sample using the calibration curve developed by different concentrations of Gallic acid standard.

The total flavonoid content of the jackfruit by-product flour sample was determined using the methods previously described by Zhishen *et al.* (1999) and Chang *et al.* (2020) with some modifications. The 1 mL of sample or quercetin standard solution or the blank solution (water) was added into a 10 mL volumetric flask. After adding 4 mL of distilled water, 0.3 mL of 5% (w/v) NaNO2 was added to the solution. After 5 min, 0.3 mL of 10% (w/v) $AlCl_3$ was added to the mixture. At 6 min, 2 mL of 1 M NaOH was added, and the solution was volume up to 10 mL with distilled water. The total flavonoid content of the sample was calculated from the absorbance at 510 nm measured after 15 minutes using an equation obtained by linear regression of a quercetin standard curve prepared by serial dilution of quercetin solution as milligrams of quercetin equivalent (QE) per 100 mL of the sample.

The DPPH assay described by Petlevski *et al.* (2013) was used with some modifications to assess the total antioxidant activity of jackfruit by-product flour. Briefly, 4 mL of 0.1 mM DPPH methanolic solution was added to 0.4 mL of extract or standard and vortex well. The samples were kept in the dark for 30 min, and the absorbance was read at 517 nm using a spectrophotometer. The results were expressed as Trolox equivalent (TE) in milligrams per millilitre of a sample using the equation obtained by linear regression of the Trolox standard curve prepared by serially diluted Trolox solution.

Preparation of pasta using composite flour with jackfruit by-product flour

Different composite flour mixtures combined jackfruit by-product flour (Jackfruit core and Rags, 1:1 (w/w)) with wheat flour using a trial-and-error method. Finally, four different composite flour mixtures were prepared using the jackfruit by-product flour and wheat flour ratios of T1 – 25:75, T2 – 35:65, T3 – 40:60, and T4 – 0:100 (w/w). The following flow diagram (Figure 1) shows the production process of pasta using different composite flour mixtures.

The prepared pasta was packed in low-density polyethylene (LDPE) and stored at ambient temperature until further use.

Sensory Evaluation

The best combination of the composite flour mixture for the preparation of pasta was selected through a sensory evaluation conducted by 30 semi-trained panelists using five-point hedonic scales. The sensory attributes such as texture, taste, aroma, color, appearance, and overall acceptability of the products were assessed. The temperature of the pasta samples was kept at 45 °C while being served. The preference for the selected pasta sample over 100% (w/w) wheat flour pasta was determined using the same method described above using a separate sensory analysis.

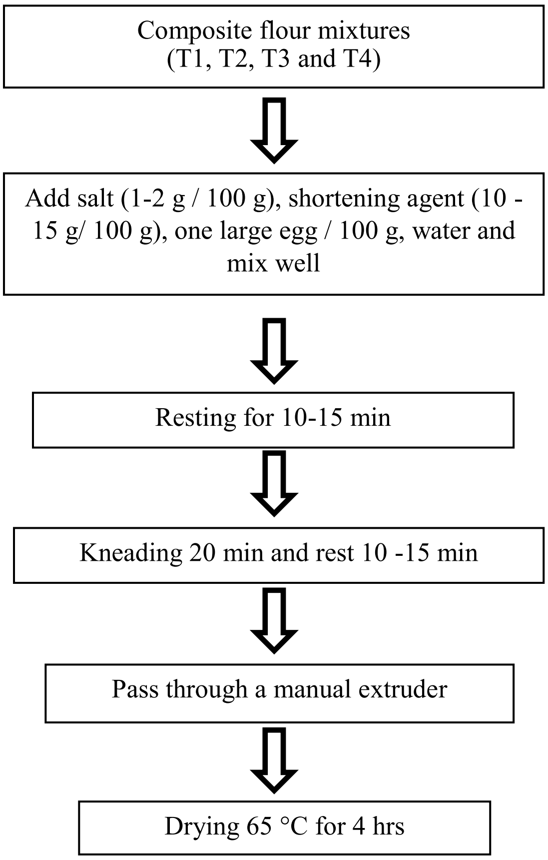

Figure 1: Flow diagram of the preparation of pasta from the composite flour mixture

Shelf-life Analysis

The samples stored in low-density polyethylene (LDPE) at room temperature (30±2 °C) were examined for color, pH, and total plate count (TPC) once every two weeks for up to six weeks. The developed product's color was measured using colorimeters (BCM -200, China), while pH was measured using a pH meter (model AD132, Romania). The total plate count was determined using the pour-plate method described by Harrigan *et al.* (1976).

Statistical Analysis

All the data are presented as mean ± standard deviation of two or three replicates. The Non-Parametric Kruskal Wallis test analyzed the sensory data using Minitab® software version 17 for Windows. One-way ANOVA with student *t*-test was applied to determine the statistical significance among the different groups at $p<0.05$ using SPSS software version 25 for Windows.

RESULTS AND DISCUSSION

Physico-functional Properties of jackfruit by-product flour

The jackfruit by-product flour showed a bulk density of 0.95 ± 0.01%, a water absorption capacity of 8.77 ± 0.06 g/g, and a swelling capacity of 46.00 ± 5.66 g/g (Table 1).

Table 1: Functional properties of jackfruit by-product flour compared with wheat flour

Functional properties	Jackfruit by-product flour	Wheat flour
Bulk Density (BD) %	0.95 ± 0.01 ^{a}	0.66 ± 0.03 ^{a}
Water Absorption Capacity (WAC) g/g	8.77 ± 0.06 ^{b}	1.74 ± 0.14 ^{a}
Oil Absorption Capacity (OAC) g/g	3.21 ± 0.06 ^{a}	1.88 ± 0.07 ^{a}
Swelling Capacity (SC) g/g	46.00 ± 5.66 ^{b}	17.35 ± 0.21 ^{a}
Gelatinization Temperature (GT) °C	79.45 ± 0.07 ^{b}	63.40 ± 0.14 ^{a}
Colour	L* = 11.14 ± 0.03 ^{a} a* = 7.75 ± 0.05 ^{a} b* = 12.21 ± 0.08 ^{a}	L* = 15.10 ± 0.01 ^{a} a* = 6.05 ± 0.01 ^{a} b* = 13.63 ± 0.02 ^{a}

Data are given as mean ± standard deviation of four independent measurements. Values with the same superscript along the rows are not significantly different at $p<0.05$, *t*-test.

The bulk density of flour is an important criterion to measure the heaviness of a flour sample. (Oladele, 2007) It mainly depends on the flour's moisture content and particle size (Ocloo *et al.*, 2010). The present study showed that jackfruit by-product flour has a higher bulk density than wheat flour. Higher bulk density is preferable in the bakery industry as it can result in more consistent dough properties and improved handling during the manufacturing process. Further, the bulk density of the flour is important to determine the type of packaging used to store the flour. The flour with lower bulk density needs less dense packaging, which would be cost-effective, and in contrast, the flour with high bulk density needs denser packaging (Masri *et al.*, 2017).

The water absorption capacity (WAC) of jackfruit by-product flour was significantly higher ($p<0.05$) than the WAC of wheat flour. Water absorption capacity is an important processing parameter that has implications for viscosity. Moreover, the thickening and consistency of products and baking applications depend on a product's ability to absorb water. Water binding mostly depends on the amount of protein and carbohydrates present in any flour type. The proteins in by-products of jackfruit may have a more hydrophilic subunit structure than the proteins in wheat flour, which can bind more water. This might be the cause of the higher WAC of jackfruit by-product flour. Moreover, the high amount of carbohydrates may result in enhanced water absorption as they can attract and hold more water due to hydrophilic properties. The study by Akubor *et al.* (2014) reported that the water absorption capacity of wheat flour and jackfruit seed flour were 0.75 g/g and 1.55 g/g, respectively. Higher WAC of flour was beneficial in bakery products as this could prevent the staling process by reducing moisture loss (Obatolu *et al.*, 2007).

Jackfruit by-product flour showed higher oil absorption capacity (OAC) compared to wheat flour, even though there was no significant difference ($p>0.05$) among samples. Oil absorption capacity is one of the desired properties in food formulations because it affects the flavour and mouthfeel of foods and is important in developing food products. Further, information on OAC can be used to determine the shelf-life of the product, optimize costs, and control product quality. (Aremu, 2007). For instance, a higher OAC of flour may result in a higher rate of rancidity.

The swelling capacity (SC) of wheat flour was significantly different ($p<0.05$) compared to the jackfruit by-product flour. Swelling capacity refers to the ability of flour to absorb water and increase its volume (Ocloo *et al.*, 2010). Therefore, it is an important characteristic for developing dough structure during the baking process and ultimately determines the product quality. The size of the particles, variety, and processing techniques or unit operations affect the SC of flours. The jackfruit by-product flour has higher SC, which helps create a light and porous texture in the final baked product. Further, higher SC can also help to retain moisture in the dough and result in a tender and moist texture in the final baked product.

The gelatinization temperature of flour is an important parameter in the baking process as it affects the formation of the dough and the texture of the final baked product. There was no significant difference ($p>0.05$) between the gelatinization temperature of jackfruit by-product flour and wheat flour. The gelatinization temperature of flour can depend on the size and form of the starch granules, the amylose concentration, the chain length, and the degree of crystallinity. The gelatinization temperature of wheat flour ranges between 55 °C to 75 °C and is considered an ideal temperature range for baking applications. The gelatinization temperature of jackfruit by-product flour was around 79 °C and lay slightly higher than the perfect temperature range due to the presence of more fiber and resistant starch.

Colour is an important sensory characteristic of food that can be used to assess its quality and acceptability to consumers. There was a significant difference ($p<0.05$) between the jackfruit by-product flour and wheat flour for the L* value. The L* value of the flour can be changed due to the different processing methods such as boiling, blanching, moisture content, chemical composition, and the particle size of flour (Huda *et al.*, 2001). Both a* and b* values of jackfruit by-product flour were not significantly different ($p>0.05$) from the wheat flour, meaning that both have the same balance of green to blue and blue to yellow tones in their color.

Proximate composition

The approximate composition, such as moisture, ash, crude fiber, crude fat, and crude protein, of jackfruit by-product flour and wheat flour was analyzed and shown in Table 2.

Table 2: Comparison of proximate composition of jackfruit by-product flour and wheat flour

Proximate composition	Jackfruit by-product flour g/ 100 g wet weight basis (wb)	Wheat flour g/ 100 g wet weight basis (wb)
Moisture	12.2 ± 0.20^{a}	18.6 ± 0.35^{a}
Ash	5.00 ± 0.70^{b}	2.50 ± 0.71^{a}
Crude protein	9.90 ± 0.99^{b}	14.15 ± 0.92^{a}
Crude fat	0.19 ± 0.06^{a}	0.35 ± 0.05^{a}
Crude fibre	13.00 ± 1.13^{b}	2.24 ± 0.23^{a}
Total carbohydrate	59.71 ± 0.01^{a}	62.16 ± 0.01^{a}

Data are given as mean ± standard deviation of four independent measurements. Values with the same superscript along the rows are not significantly different at $p<0.05$, *t*-test.

The results showed no significant difference ($p>0.05$) in moisture content between jackfruit by-product flour and wheat flour. The study conducted by Singh *et al.* (1991) found that the moisture content of flour obtained from jackfruit bulbs was around 15.19 ± 0.01%, and Opkala *et al.* (2010) and Ocloo *et al.* (2010) reported that the jackfruit seed flour contains around 6.09% moisture. Therefore, the moisture content of jackfruit by-product flour was lower than that of jackfruit bulb flour, and it is a favourable attribute for keeping the quality of the flour for further use. Food quality is also affected by the moisture content and packaging type and conditions. Excess moisture content can lower the product's resistance to micro-organisms while increasing the enzyme activity. This causes a shortening of the shelf-life of the food product, which leads to food waste. Thus, the lower moisture content of jackfruit by-product flour is a preferable attribute, which indirectly indicates the flour's longer shelf-life.

The total ash content of jackfruit by-product flour was 5.00 ± 0.71 g/100 g wb, significantly higher ($p<0.05$) than the ash content of wheat flour. Generally, total ash content represents the mineral content present in a food product, and the present study showed that jackfruit by-product flour contains more mineral content than wheat flour. The study conducted by Ocloo *et al.* (2010) and Eke-Ejiofor *et al.* (2014) reported that the ash content of jackfruit seed flour ranged between 2.45 to 2.76%. Siti Faridah *et al.* (2012) and Karim *et al.* (2008) reported that the ash content of jackfruit bulb flour and jackfruit pulp ranged from 1.11 to 0.70%. However, the ash content of jackfruit by-product flour was significantly higher than those reported values.

The crude protein content of jackfruit by-product flour was 9.99 ± 0.99 g/100 g wet basis (wb) while wheat flour showed 14.15 ± 0.92 g/100 g wb crude protein content. **Wheat flour was a great source of protein**, and the present study showed that wheat flour had 1.42 ± 0.23 times higher crude protein than jackfruit by-product flour. It is well-known that wheat flour is naturally higher in crude protein than other grains. For instance, whole-wheat flour contains 13–14% protein content. The crude protein content of jackfruit seed flour and jackfruit bulb flour was around 14.18% and 1.3%, respectively (Ocloo *et al.*, 2010; Eke-Ejofor *et al.*, 2014). Jackfruit seed flour contains a higher amount of crude protein content compared to jackfruit bulb flour. This higher crude protein content present in jackfruit by-product flour is important, especially when developing food products for vegan people. Because that of plant origin can replace the protein from animal origin for appreciation of the nutritional properties of the food products. However, there is limited research available on the composition of the protein available in jackfruit by-product flour.

There was no discernible difference in the crude fat content of wheat flour and jackfruit by-product flour ($p>0.05$). Fat content significantly impacts a food product's quality and shelf life. Foods with a high fat content are undesirable because they can be rapidly rancid and produce off-flavors and smells.

Jackfruit by-product flour showed significantly higher ($p<0.05$) crude fibre content compared to the wheat flour. The reason could be that the jackfruit core and rags contain a higher percentage of cell wall materials and are processed less than wheat flour. A study conducted by Ocloo *et al.* (2010) reported that the crude fibre content of jackfruit seed flour was around 3.19%, while Coronel (1983) reported that the crude fibre content of jackfruit pulp was around 0.6%. Both reported values were lower than the crude fiber content reported for by-product flour in the present study. Therefore, jackfruit by-product flour contains a high amount of fibre, and fibre-rich foods are good sources to improve digestive health, promoting regular bowel movements and preventing constipation, as well as people who are keen to reduce body weight as consumption of high -fibre foods promote a feeling of fullness.

Antioxidant properties

Antioxidants offer many health benefits, including preventing cell damage caused by oxidation and reducing the risk of non-communicable diseases such as cancer, diabetes, etc. Further, the presence of some antioxidants helps to prevent the oxidation of fats and oils and thereby increase the shelf-life of flour. The antioxidant activities of jackfruit by-product flour are shown in Table 3.

Table 3: Antioxidant activities of jackfruit by-product flour

Antioxidant properties	Jackfruit by-product flour
Total phenolic content	40.91 ± 0.03 mg GAE/ 100 g
Flavonoid content	65.70 ± 0.02 mg QE/ 100 g
Antioxidant content (DPPH assay)	8.46 ± 0.01 mg TE/100 g

*All values are presented in mean ± standard deviation of four independent measurements.

The present study showed that jackfruit by-product flour was rich in polyphenols and flavonoids while showing 8.46 ± 0.01 mg TE/100 g antioxidant activity. The total polyphenol content of jackfruit seeds was reported as 2.12 ± 0.01 g Gallic acid/ mg extract. The TPC amount of the food greatly depends on the extraction technique and solvent. Further, the antioxidant activity of the jackfruit can vary depending on the variety, soil conditions, fertilizer, maturity stage, and postharvest handling.

Evaluation of Sensory properties of developed pasta

The sensory results of pasta developed using the three different composite flour mixtures are shown in Table 4. The results showed that Treatment 3 (T3) obtained significantly lower ($p<0.05$) mean rank values for texture, taste, aroma, colour and overall acceptability compared to the other two treatments. The reasons could be that the T3 contains more jackfruit by-product (40% w/w) flour and results in a coarse structure than the other samples. Therefore, Treatment 1 (T1), which obtained a higher mean rank value, was selected as the best treatment and stored at ambient temperature for further analysis.

In addition, a second sensory analysis was conducted to compare the selected best treatment with pasta made with 100% (w/w) wheat flour. The results showed that there was no significant difference ($p>0.05$) between the two treatments for the sensory attributes of texture, taste, aroma, appearance, and overall acceptability, which means that the developed pasta product is organoleptically similar to the regular pasta we consume.

Proximate composition of developed product

The result of the proximate composition of the selected best product through sensory analysis is summarized in Table 5.

Table 5: Proximate composition of Developed pasta product

Proximate composition	g/ 100 g wet weight basis
Moisture content	1.19 ± 0.33
Ash content	2.75 ± 0.47
Crude protein content	10.50± 0.99
Crude fat content	0.35 ± 0.03
Crude fibre content	12.21± 0.27

All values are mean ± standard deviation of four independent measurements.

The proximate data showed that the developed pasta product was rich in crude protein compared to the jackfruit by-product flour, and this may be due to the preparation of a composite mixture with wheat flour. Further, the developed products showed higher crude fibre content, but slightly lower than the crude fibre content of jackfruit by-product flour.

Shelf-life of the developed pasta

No colonies were observed initially and during the 6 weeks of storage period. This may be due to the use of high-quality raw materials and the hygienic preparation of pasta. Further, developed pasta products have lower moisture content than commercially available wheat flour pasta. The moisture content is important when storing pasta since high moisture levels may result in undesirable chemical and microbiological changes. The pH of the developed product was changed

Table 4: Mean rank values of pasta produced with three different mixtures of composite flour

Treated sample	Texture	Taste	Aroma	Colour	Appearance	Overall acceptability
T1	56.48±0.96^{a}	58.45±1.06^{a}	53.60±0.99^{a}	50.39±1.02^{a}	58.24±0.94^{a}	57.76±0.87^{a}
T2	53.15±0.81^{a}	47.95±0.99^{a}	52.81±1.06^{a}	50.32±0.96^{a}	50.65±0.72^{a}	50.65±0.99^{a}
T3	31.37±1.03^{b}	34.60±1.25^{b}	34.60±1.10^{b}	40.29±1.15^{a}	32.11±1.03^{b}	33.50±1.18^{b}

Means with the same superscript within the same column are not significantly different at $p>0.05$.

between 4.99 – 4.97 during the 6 weeks of storage period. The main reason for changing the pH of the pasta during the storage period might be the action of microbial spoilage.

The results showed that all the tested colour parameters of the pasta were decreased during the storage period. The decrease of the L* value means a reduction in the product's lightness, while the decline in the a* and b* values indicates the increase of green and blue colour, respectively. The reason for changing the colour value may be the oxidation of the pasta product due to exposure to oxygen and light exposure, which causes the degradation of colour pigments and temperature fluctuations.

CONCLUSION

The current investigation demonstrated the potential for jackfruit by-product flour to be used in the production of pasta. The proximate study revealed that the flour made from jackfruit byproducts had higher crude fiber content than wheat flour. The flour made from jackfruit byproducts also demonstrated strong antioxidant properties. It can be concluded that the developed pasta product can be stored in Low-Density Polyethylene (LDPE) packages under ambient temperature for nearly 6 weeks without changing its quality. Further studies need to be conducted to find the cooking quality (before and after boiling) and extended shelf-life of the developed pasta product.

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AUTHOR CONTRIBUTION

GSNF, HAD, and APHIA designed the study; HAD performed the experiments; GSNF and HAD analyzed the data and wrote the original draft; and GSNF and APHIA edited the manuscript.

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