

Received: 31 January 2024

Accepted: 14 June 2024

Evaluation of Functional Characteristics of Jackfruit Seed Flour and Its Application in Developing a Nutrient-Dense Snack

Gunarathna, R. W. M. M.¹, Samarakoon, E. R. J.¹ & Janith, R. M. L.²

maneeshamadumani@gmail.com, rasanjalis@agri.pdn.ac.lk, lakshanjanith99@gmail.com

¹Department of Food Science and Technology, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

²Yako Products (Pvt) Ltd, No102, Janapadaya, Okkampitiya, Sri Lanka.

Abstract

Deep-fried snacks contain high calories and fat. Jackfruit seeds are nutrient-dense and contain a high level of carbohydrates and proteins with relatively low-fat content. This study was conducted to evaluate the functional properties of jackfruit seed flour and develop a snack. Jackfruit seeds were processed using three different methods: roasting, oven drying, and boiling. Flour produced from the boiling method contained the highest moisture content (7.04%), water-holding capacity (2.08 g/g), bulk density (0.81 g/cm³), oil-holding capacity (2.04 cm³/g), swelling power (6.91%), and the lowest solubility (7.69%). Flour made from the roasting method showed the lowest oil-holding capacity (1.84 cm³/g). The snack was prepared using the extrusion technique, and the flour mixture contained jackfruit seed flour, rice flour, and wheat flour in a 4:1:1 ratio. The frying time for the snacks prepared using roasted, boiled, and oven-dried jackfruit seed flour was 15, 17, and 10 seconds, respectively. Boiled jackfruit seed flour-based snacks obtained the highest consumer preference. Proximate analysis showed that the boiled jackfruit seed flour-based snack contained 83.61% carbohydrate, 4.74% moisture, 6.46% fat, 2.90% ash, 1.70% fibre, and 0.59% protein. The result of this study demonstrated that jackfruit seed flour can be effectively utilized to produce a low-fat snack with a favourable nutritional profile.

Keywords: Deep-frying, Flour based-snacks, Functional properties, Jackfruit seed flour.

Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the family Moraceae (mulberry family). The jackfruit tree is a large tropical fruit crop and is native to Southwestern India. It is widely cultivated in tropical regions around the world, including India, Sri Lanka, Malaysia, Indonesia, Thailand, the Philippines, etc. Also, it can be seen in Africa, Brazil, Suriname, and Florida. (Doijode, 2020). Due to the largest fruit size, it is considered the largest tree-born fruit, as some individual fruits weigh up to 30-36 kg. The jackfruit tree is medium-sized and evergreen. It has a conical or pyramidal-shaped canopy, and its leaves are dark green. When considering the fruit, it contains oblong, cylindrical-shaped fruits, and its length is about 30-40 cm, but it can be increased up to 90 cm. The fruits can be compound or multiple with a yellow-brown exterior rind. Fruits take 90-180 days to reach their maturity level. Jackfruit seeds are light brown, 2-3 cm in length, with a diameter of 1-1.5 cm, and the fruit contains up to 500 seeds (Prakash *et al.*, 2009). Jackfruit seeds account for 12% of the total fruit. Raw jackfruit seeds contain 4.27% ash, 6.73% protein, 73.34 % starch, 1.6% fibre, and 0.8% fat (Noor, 2014). Thus, jackfruit seed flour can be used as an alternative to wheat flour, which may reduce the post-harvest loss of jackfruit seeds and assist the development of nutritious food products (Noor, 2014). Previous studies have investigated the functional properties of various alternative flours, highlighting their potential for food applications. Hadnadev *et al.* (2011) studied the rheological properties of rice, corn, buckwheat, amaranth, and soybean flours, comparing them to those of wheat flour. In another study, the physical, chemical, and functional properties of composite flours made with cassava, rice, and soybean flours, along with potato starch and 0.5% xanthan gum were examined and found

that certain composite flour mixture exhibited physicochemical, functional and pasting properties comparable to those of wheat flour (Tharise *et al.*, 2014). Chandra and Samsheer (2013) evaluated the functional properties of various flours and concluded that green gram flour and potato flour possess good functional properties which enhance the nutritional quality of value-added food products. These studies collectively underscore the importance of selecting flour blends based on targeted functional properties.

Snack is a light meal, eaten in between main meals (Pikuda & Ilelaboye, 2009), and a deep-fried snack is a food that is immersed in hot oil, resulting in a crispy golden surface, and a flavourful interior (Gupta, 2019). These deep-fried snacks contain high levels of fat and calories, and have low nutrient content (Pikuda & Ilelaboye, 2009), which may lead to negative health effects. To mitigate these negative effects, snacks made from jackfruit seed flour can be used as an alternative, as this flour is high in protein, fibre, and B-complex vitamins, and exhibits low oil absorption (Waghmare *et al.*, 2019). Also, it gives numerous health benefits to the human body, such as reducing the risk of heart diseases, preventing constipation, promoting weight loss due to high fibre content, controlling blood sugar, and keeping the gut healthy due to resistant starch, etc. (Waghmare *et al.*, 2019). Considering the properties of the jackfruit seeds and their nutritional composition, there is potential to develop nutritional and value-added products using jackfruit seed flour. While there are numerous studies on jackfruit seed flour, research on products made from jackfruit seed flour is limited. In particular, the development of deep-fried snacks using jackfruit seed flour is a novel area within jackfruit-based research. Therefore,

this study aims to produce jackfruit seed flour using different methods and develop a marketable, nutrient-dense snack.

Materials and Methods

Seed treatment

Jackfruit seeds (*Artocarpus heterophyllus*) of the “Wala” variety had been collected and processed by carefully removing the white aril and washing thoroughly. Damaged or germinated seeds were removed during sorting.

Flour preparation

Based on the preliminary trials and previous literature, jackfruit seed flour was prepared using three methods: boiling, oven drying, and roasting. The method described by Ejiofor *et al.* (2014), with slight modifications, was used in these three methods. In the oven drying method, seeds (5 kg) were cleaned, and white arils were removed. The seeds were cut into 4 mm slices and placed in the drying trays. The slices were dried at 60 °C (8.1 m³/min air flow rate) for 6h using a food dehydrator (model-LM 156, Lanly manufactures, U.S.A). In the boiling method, seeds (5 kg) were cleaned and boiled for 30 min at 100 °C, and the white aril was removed manually. The seeds were cut into 4 mm slices and placed on the trays as a thin layer (3 kg/m³). The sliced seeds were dried at 60 °C (8.1 m³/min air flow rate) for 8h using a food dehydrator (model-LM 156, Lanly manufactures, U.S.A). In the roasting method, seeds were cut into 4 mm slices. These slices were placed in the air fryer (model HD9216, China) as one thin layer, and roasting was done at 160 °C for 15 min. The dried slices from all three methods were ground into flour separately, packed in low-density polyethylene bags, and stored in airtight containers.

Determination of flour properties

Flour yield

Flour yield was determined using the method of Dey *et al.* (2015). The initial weight of the seed was measured after cleaning and sorting. After drying into flour, the weight of the flour was recorded. The flour yield was calculated using the formula (1).

$$\text{Flour yield (\%)} = \frac{\text{Weight of the flour}}{\text{Weight of the seed sample}} * 100 \quad (1)$$

Bulk density

A method described by Falade and Okafor (2015) with slight modifications was used to determine bulk density. A 10 ml graduated cylinder was filled with 2.0 g of sample. The cylinder was repeatedly tapped until the volume became constant. The final volume of flour in the cylinder was taken, and the bulk density was calculated using the equation (2).

$$\text{Bulk Density (g/cm}^3\text{)} = \text{Weight (g)/ Volume (cm}^3\text{)} \quad (2)$$

Moisture content

Analysis of the moisture content was conducted using the standard oven-dry method. After weighing and adding 5.0 g of sample to a moisture can, the can was placed in a hot air oven (SPF600, SIBATA, Japan) set at 105 °C. The weight of the can was then measured every 2 h until it became constant. The formula (3) was used to get the dry basis moisture content.

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight of the sample} - \text{Dry weight of the sample}}{\text{Dry weight of the sample}} * 100 \quad (3)$$

Water holding capacity and oil holding capacity

A centrifugal technique described by Islam *et al.* (2015) was used to analyse the water-holding capacity (WHC) and oil-holding capacity (OHC) of the samples. A weighed centrifuge tube was filled with 0.5 g of the sample, and either 5 ml of distilled water or coconut oil was added. Following a 2-minute mixing period at room temperature, the weight of the tube containing the slurry was

recorded. A centrifuge (H-100F, KOKOSAN Corporation, Japan) was used to spin the tube for 10 minutes at 3000 rpm and 5 minutes at 4000 rpm. After removing the supernatant, the precipitate-containing tube's weight was determined. A measuring cylinder was used to determine the volume of decanted oil. The formulas below were used to determine WHC and OHC.

$$\text{WHC (g/g)} = \frac{\text{Mass of water added to the sample} - \text{Mass of water removed from the sample}}{\text{Mass of the sample}} \quad (4)$$

$$\text{WHC (g/g)} = \frac{\text{Mass of water added to the sample} - \text{Mass of water removed from the sample}}{\text{Mass of the sample}} \quad (5)$$

Water solubility

A modified method of Islam *et al.* (2015) was used to measure the water solubility of the jackfruit seed flour. A 0.5 g sample of jackfruit seed flour was weighed into the weighed centrifuge tube (50 ml), and 10.0 ml of distilled water was added into the tube. The tube was heated at 95 °C for 30 min using a water bath. The tube was allowed to cool to room temperature without mixing. Then samples were centrifuged at 1600 rpm for 15 minutes and 2000 rpm for 5 minutes and using a weighed evaporating dish, the supernatant was collected. It was dried at 105 °C for 3 h using a hot air oven (Kalstein DHG -9070A, China), and the final weight was taken. Water solubility was calculated using the formula (6).

$$\text{Water solubility (\%)} = \frac{\text{Weight of the soluble sample}}{\text{Initial weight of the sample}} \quad (6)$$

$$\text{Watersolubility (\%)} = A = \pi r^2$$

Swelling power

The modified method described by Islam *et al.* (2015) was used to measure the swelling power of the jackfruit seed flour. A 0.1 g of flour sample was mixed with 10.0 ml of distilled water in a centrifuge tube (50 ml). Then the tube was heated at 95 °C for 30 min using a water bath and gently mixed. Then the sample was cooled to room temperature and centrifuged at 1600 rpm for 15 minutes and 2000 rpm for 5 minutes. Then supernatant was discarded, and the weight of the tube was taken with the sediment paste. The swelling power was calculated using equation (7).

$$\text{Swelling power (gg)} = \frac{\text{Weight of the sediment paste}}{(1-\text{Water solubility})} * \text{weight of the sample} * 100 \quad (7)$$

Preparation of the jackfruit seed flour-based snack

Determination of the most promising flour ratio for the development of a snack

Experiments were conducted on the prepared flour samples to determine the most suitable flour ratio for snack development. Here, mainly considered the most suitable flour combination and the ratio were considered according to the dough forming ability, elasticity, stickiness, and deformation, and the best formulation and the ratio were selected. In addition to jack fruit seed flour, corn, rice, black gram and wheat flour were used in different ratios to develop the composite flour (Table 1).

Table 1.
Flour combinations with different ratios.

Flour combination	Flour Ratio
A	Corn 50: Jackfruit 50
B	Corn 30: Jackfruit 70
C	Corn 10: Jackfruit 90
D	Jackfruit 4: Black gram 1: Wheat 1
E	Jackfruit 2: Black gram 1: Wheat 1
F	Jackfruit 4: Wheat 1: Rice 1
G	Jackfruit 2: Wheat 1: Rice 1

Salt (1.0 g) was added to 100 g of each flour mixture. Then water (20.0 ml) was added until the flour mixture became a soft dough. Each dough was covered with a wet cloth and kept for 10 minutes. Then using a rolling pin, the dough was spread into the thin sheet.

Finally, it was cut into the required shape. To enhance crispiness, further experiments were conducted using different processing methods.

Determination of a method to increase the crispiness of the snack

Even though the thickness of the snack should be reduced to increase the crispiness, due to the stickiness of the dough, it was difficult to reduce the thickness on the laboratory scale. Therefore, the following techniques were tested to determine the best method to increase the crispiness.

Baking

Baking was done using two methods. In the first method, the dough was prepared using jackfruit seed flour, wheat flour, and rice flour in a 4:1:1 flour ratio, spread into thin sheets as much as possible and cut into particular shapes. Then those snack pieces were baked at 160 °C for 10 minutes, followed by deep frying. As the second method, the dough was prepared using jackfruit seed flour, wheat flour and rice flour in a 4:1:1 flour ratio. Then 10.0 g of butter and 35.0 ml of water were added, and the mixture was cooked on a lower heat to obtain a thick batter. This thick batter obtained 2-3 mm thick, 4 cm diameter snacks. Snacks were baked in 160 °C for 20 minutes.

Roasting

The dough was prepared using jackfruit seed flour, wheat flour, and rice flour in a 4:1:1 flour ratio. Then it was spread into thin sheets as much as possible and cut into particular

shapes. Then those pieces were roasted using an air fryer for 8 minutes at 160 °C. Then air-fried snacks were deep fried using coconut oil.

Extrusion

The dough was prepared using jackfruit seed flour, wheat flour, and rice flour in a 4:1:1 flour ratio. Then water (20.0 ml) was added until it became a wet flour mixture. Then the flour mixture was added into the extruder (DOLLY 11F080), and the extruded snack was obtained. The snack was air fried for 4 minutes at 160 °C followed by deep frying.

Selection of the final product processing method

Considering the different attributes of the snack, the extrusion method was selected as the method for snack making. Extruded snack was developed using the three types of jackfruit seed flour (boiled, roasted, and oven-dried jackfruit seed flour). The prepared snack was deep fried at 160 °C using a laboratory deep fryer at different frying times (Table 2).

Table 2.
Frying time of extruded jackfruit seed flour-based snacks.

Snack type	Frying time (seconds)
Boiled jackfruit seed flour-based snack	17
Roasted jackfruit seed flour-based snack	15
Oven-dried jackfruit seed flour-based snack	10

Determination of color

A colorimeter (CS10 CHN – Spec, China) was used to determine the color of the jackfruit seed flour and snack. The L*, a*, and b* parameters were measured using the colorimeter.

Sensory evaluation

A seven-point hedonic test was conducted with thirty untrained panellists, 16 female students and 14 male students from the Faculty of Agriculture at the University of Peradeniya to select the best snack type from the three variations. The panellists evaluated the prepared snacks based on their texture, taste, color, aroma, and overall acceptability.

Proximate composition analysis of the final product

Proximate analysis was conducted on the product selected from the sensory evaluation (the snack developed from boiled jackfruit seed flour), following the AOAC Official Method 920.39, 2019. The analysis included the measurement of moisture, ash, crude protein, crude fat, crude fibre, and carbohydrate content of the product.

Statistical analysis

The functional property parameters were presented as mean ± SD, and one-way analysis of variance (ANOVA) was conducted for all tested parameters using the linear model of the complete randomized design (CRD). The pairwise comparison was conducted using the Tukey's multiple comparison test at 5% level. The nonparametric data in sensory evaluation were analysed using the Friedman test. All

the statistical data were analysed using the Minitab® 19 software.

Results and Discussion

Flour yield

The weight percentage of the jackfruit seed coat was 4-6%, rendering it unusable. The flour yield obtained by roasting, boiling, and oven drying was 35.26, 41.72, and 35.67%, respectively. These yields were lower than the yield (46%) reported by Roy Chowdhury *et al.* (2012), and it could be due to the variations in the flour preparation methods. The seeds were milled using a laboratory grinder. Yield could be improved by utilizing a more suitable milling machine, as the seeds become very hard after drying, making the milling process challenging. In the milling of seeds, the higher the degree of milling greater the nutrient losses, and this tends to increase the starch content (Devi, 2015). However, the higher degree of milling helps to increase the quality of the final product and flour yield. Therefore, it is important to maintain a proper balance between product quality and nutritional aspects. Before drying, the seeds should be cut into smaller pieces to facilitate moisture removal. Reducing the thickness enhances the drying process; however, manual cutting poses challenges, limiting the thickness to 0.5–0.8 cm.

When comparing the yield of the above three methods, the boiling method resulted in the highest yield. During the boiling process, starch granules become disintegrated, and it facilitates the milling process. That may help to increase the yield. Also, it helps to destroy the trypsin inhibitors present in the seeds (Juárez-Barrientos *et al.*, 2017). In the flour-

making process, the brown color spermoderm was not removed. It contains various phenolic compounds, such as (tannin) (Prakash *et al.*, 2009), that help to increase the color of the final product. During roasting, the high heat and the circulating air cause rapid removal of moisture from the jackfruit seed. As a result, the jackfruit seed particles become dehydrated and undergo textural transformation. Furthermore, roasting enhances the flavor by caramelizing the sugars. Also, Millard browning reactions occur between the amino acid and reducing sugars due to the higher temperature, and as a result flavor and color development can be seen (Arafat, 2014). Therefore, compared to the other two methods, the flour obtained from roasting method showed characteristic color and flavor. When the seeds are boiled, heat causes starches to gelatinize, breaking down complex carbohydrates into simple sugar. As a result, the final product that was developed using boiled jackfruit seed flour has a sweeter taste than the other two methods of flour (Juárez-Barrientos *et al.*, 2017).

Functional properties of jackfruit seed flour

There was no significant difference ($p > .05$) in the moisture content of all three treatments, but the moisture levels ranged from 5.73 to 7.40% (Table 3). These values were higher than the values (3.20 to 6.60%) reported by Ejiofor *et al.* (2014). Boiled jackfruit seed flour had the highest moisture content (7.40%) due to higher water absorption during the boiling. The roasted flour sample exhibited the lowest moisture content due to the rapid moisture loss caused by higher temperatures over a shorter duration. Consequently, the roasting method demonstrated greater moisture

removal efficiency compared to the other two methods. Therefore, roasted flour contains lower moisture content (Arafat, 2014).

There were significant differences ($p < 0.05$) between the oven-dried flour and the other samples with respect to bulk density (Table 3). But there is no significant difference ($p > 0.05$) in bulk density between roasted and boiled seed flour. Accordingly, boiled flour had the highest bulk density (0.81 g/cm^3) due to its higher moisture content. The oven-dried flour had the significantly lower (0.62 g/cm^3) bulk density that other two treatments. During the roasting process, rapid heating and drying occur within a shorter period, which leads to the shrinking and packing of the flour particles tightly, resulting in a higher bulk density compared to that of the boiled flour sample.

Some significant differences ($p < 0.05$) were noted in the water holding capacity, with boiled flour having the highest (2.08 g/g) and oven-dried flour the lowest (1.21 g/g), and these values were reported lower than the values (4.0 g/ml to 6.0 g/ml) reported by Ejiofor *et al.* (2014) which could be due to the variations in the flour preparation methods. Water absorption capacity is important for the consistency of the product, bulking, and baking application (Ejiofor *et al.*, 2014). No significant differences ($p > 0.05$) among the samples were observed with respect to their oil holding capacity, with values ranging from

1.84 to $2.04 \text{ cm}^3/\text{g}$; however, boiled flour had the highest oil-holding capacity. These values were similar to those of reported by Ejiofor *et al.* (2014) (1.5 g/ml to 3.0 g/ml). Oil absorption is an important property in food product development, especially for flavor development and the mouth feel (Ejiofor *et al.*, 2014).

A significant difference ($p < 0.05$) was observed in the swelling power of roasted, boiled, and oven-dried seed samples, ranging from 6.00 to 8.26 g/g . (Table 3). The boiled flour exhibited the highest swelling power (8.26 g/g), while the oven-dried sample had the lowest (6.00 g/g). These values are comparable to those reported by Ejiofor *et al.* (2014), which ranged from 6.58% to 9.46% . Swelling power is a key factor influencing the eating quality of food, as it reflects the ability of starch granules to absorb water and expand (Ocloo *et al.*, 2010).

There was a significant difference ($p < 0.05$) among the solubility of the flour samples, ranging from 7.69 to 11.40% , with roasted flour having the highest solubility and the lowest solubility reported in boiled seed flour (7.69%). This variation aligns with findings by Ejiofor *et al.* (2014), who reported solubility values between 8.24% and 14.48% . Solubility reflects the extent of intermolecular cross-bonding within the granule (Ejiofor *et al.*, 2014).

Table 3.
Functional properties of jackfruit seed flour.

Treatment	Moisture (%)	Bulk density (g/cm^3)	Water holding capacity (g/g)	Oil holding capacity (cm^3/g)	Solubility (%)	Swelling power (%)
Roasting	5.73 ± 1.17^a	0.76 ± 0.04^a	1.79 ± 0.21^a	1.92 ± 0.31^a	0.14 ± 0.07^a	8.93 ± 1.67^a
Boiling	7.40 ± 0.38^a	0.81 ± 0.04^a	2.08 ± 0.12^a	2.04 ± 0.12^a	0.11 ± 0.05^a	6.91 ± 0.53^{ab}
Oven drying	6.48 ± 0.51^a	0.62 ± 0.07^b	1.21 ± 0.15^b	1.91 ± 0.22^a	0.10 ± 0.01^a	5.67 ± 0.89^b

Values are in means \pm SD (n=3). Mean (\pm SD) followed by the same subscript within a column is not significantly different ($p>0.05$) as measured by the Turkey test.

Determination of suitable flour mixture

The flour mixture containing corn flour and jackfruit seed flour exhibited higher stickiness, and it could be due to the high starch content and lack of gluten in corn flour (Aini *et al.*, 2018). When water was added, starch granules absorb the water and swell, creating a sticky, thick consistency. In contrast, the flour mixture containing black gram flour, wheat flour, and jackfruit seed flour demonstrated reduced stickiness and improved crispiness compared to the corn flour mixture; however, the texture was still not at an acceptable level. The flour mixture containing rice flour, wheat flour, and jackfruit seed flour showed highest crispiness and lowest stickiness compared to the other two flour mixtures. Therefore, the flour mixture containing rice flour, wheat flour, and jackfruit seed flour in 4:1:1 ratio was selected for further development of the snack.

Determination of dough processing method

In the baking method, even though the snacks exhibited high crispiness, they tended to adhere to the baking trays, and the flavour was not at an acceptable level. Additionally, the dough-making process resulted in reduced palatability. Due to these limitations, baking was not considered for further development. In the roasting method, both the crispiness and the flavour of the product were at an acceptable level. However, the process required forming thin sheets (0.2 cm) from the dough, which was challenging due to its stickiness. In contrast, the extrusion method produced snacks with superior crispiness,

texture, appearance, and flavour compared to the other two methods. As a result, extrusion was selected for snack processing.

Frying time

After extrusion, the snacks were air-fried to enhance crispiness and flavour while reducing excessive oil absorption. The frying time varied according to the type of flour used in the snack preparation and was determined based on the flavour, color, and texture of the final product, as shown in Table 2. Deep-frying was done at 160 °C. According to the previous research reported by Awuchi *et al.* (2019), ideal frying temperature for deep frying is between 160 to 190 °C. Frying time varies according to the flour types that are used for the snack preparation.

Color Colordetermination of flour and snacks

Color measurements of the jackfruit seed flour are presented in Table 4. The **color** color of the flour varied depending on the type of flour due to differences in processing methods. In the preparation of roasted seed flour, seeds were heated at 160 °C, resulting in a Maillard browning reaction, which imparts a characteristic color and flavour. Similarly, in the boiled seed flour preparation method, the seeds were subjected to high temperatures, leading to a change in flour color. Therefore, there was a noticeable color variation among the different types of flour.

Table 4.
Color variation of jackfruit seed flour.

Treatment	L*	a*	b*
Roasting	78.67 ± 0.48 ^a	7.10 ± 0.22 ^a	12.36 ± 0.77 ^a
Boiling	76.26 ± 0.76 ^b	6.59 ± 0.11 ^{ab}	10.43 ± 0.53 ^b
Oven drying	83.19 ± 1.03 ^c	6.23 ± 0.37 ^b	6.55 ± 0.45 ^c

Values are in means ±SD (n=3). Mean (±SD) followed by the same subscript within a column is not significantly different (p>0.05) as measured by the Turkey test.

Color variations of jackfruit seed flour-based snacks are presented in Table 5. There were no significant color differences (p>0.05) among the snack samples as the deep-frying process was monitored to achieve the desired snack color.

Table 5.
Color variation of jackfruit seed flour-based snack.

Treatment	L*	a*	b*
Roasting	32.23± 0.12 ^a	-0.77 ± 0.38 ^a	1.97 ± 0.42 ^a
Boiling	31.86 ± 1.73 ^a	0.61 ± 0.59 ^a	3.06 ± 0.32 ^a
Oven drying	33.11 ± 2.34 ^a	1.15 ± 1.49 ^a	3.08 ± 2.21 ^a

Values are in means ±SD (n=3). Mean (±SD) followed by the same subscript within a column is not significantly different (p>0.05) as measured by the Turkey test.

Sensory analysis

The sensory analysis results indicated that snacks made from boiled jackfruit seed flour received the highest scores across all tested attributes (Figure 1). Consequently, boiled jackfruit seed flour-based snack was selected as the most acceptable option among consumers. Ejiofor et al. (2014) reported that different processing methods, including boiling significantly affect the functional and compositional properties of jackfruit seed flour, thereby influencing the quality of the final product. Since boiled jackfruit seed flour contains the highest moisture content, bulk density, water holding capacity, and oil holding capacity among the samples, these enhanced functional properties contributed to obtain highest consumer acceptability.

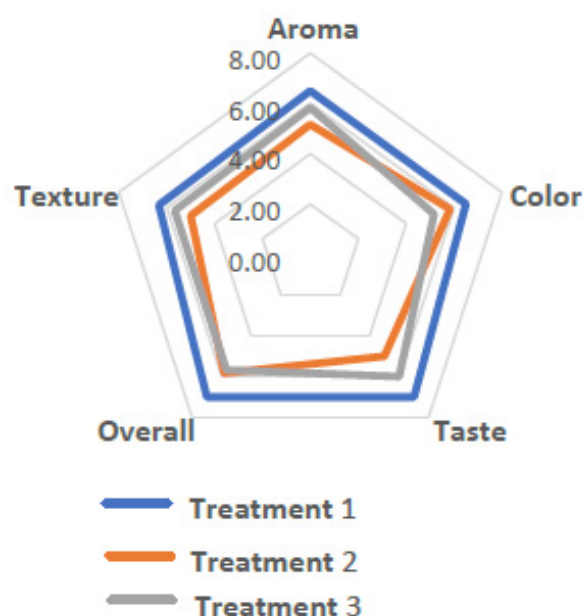


Figure 1.
Radar chart of sensory evaluation.

Treatment 1- Boiled jackfruit seed flour-based snack, Treatment 2- Roasted jackfruit seed flour-based snack, Treatment 3- Oven-dried jackfruit seed flour-based snack.

Proximate analysis

A proximate analysis of the selected boiled jackfruit seed flour-based snack is shown in Table 6.

Table 6.
Proximate analysis of boiled jackfruit seed flour snack.

Component	Amount (%)
Moisture	4.74
Ash	2.90
Fat	6.46
Fibre	1.70
Protein	0.59
Carbohydrate	83.61

Carbohydrates were the predominant component in the boiled jackfruit seed flour-based snack, comprising 83.61% of the content, while protein was the lowest. The fat content of the final product was 6.46%, which is lower compared to other deep-fried snacks (13.5%) (Pikuda & Ilelaboye, 2009). The protein content in the final product (boiled jackfruit seed flour-based snack) was lower than the protein content in the jackfruit seed flour, which is reported (Dey *et al.*, 2015) as 5.78%. This can be due to the higher thermal application during the flour and snack preparation.

During boiling, the seed was heated to 100°C, and when air frying and deep frying, a

temperature of 160°C was used. This higher temperature leads to protein denaturation or breakdown. During the processing method, due to higher temperature, Millard browning-like reaction can occur. Therefore, it can alter the protein content or make it less accessible for measuring using the Kjeldhal method.

Conclusions

In this study, a jackfruit seed flour-based snack was prepared by deep frying. Flour was prepared using three different methods: roasting, boiling, and oven drying. Other than jackfruit seed flour, rice flour and wheat flour were used for the flour mixture, which helped form a soft dough, reduced stickiness, and enhanced the crispiness of the snack. Among the snack processing methods evaluated, the extrusion method produced a snack with superior texture and crispiness compared to baking and roasting. The findings suggested that deep-fried snacks can be successfully made using boiled, oven-dried, and roasted jackfruit seed flour. Sensory evaluation indicated that boiled jackfruit seed flour-based snacks had the highest consumer acceptability. Proximate analysis revealed that carbohydrates were the major component (83.61%) in boiled jackfruit seed flour-based snack, while the fat content was lower (6.46%) than that of conventional deep-fried snacks. The low protein content (0.59%) of the snack may be a limitation. Based on these findings, jackfruit seed flour, especially boiled jackfruit seed flour can be recommended as a potential ingredient for developing healthier snacks. Protein content can be improved by incorporating protein-rich ingredients during the preparation process.

Acknowledgment

The authors would like to acknowledge the Department of Food Science and Technology, Faculty of Agriculture, University of Peradeniya, Sri Lanka for facilitating this research study. They sincerely thank Yako Products (Pvt) Ltd for the guidance and assistance provided.

References

- Aini, N., Prihananto, V., Wijonarko, G., Sus-triawan, B., Dinayati, M., & Aprianti, F. (2018). Formulation and characterization of emergency food based on instan corn flour supplemented by instan tempeh (or soybean) flour. *International Food Research Journal*, 25(1), 287–292.
- Arafat, S. (2014). Air Frying a New Technique for Produce of Healthy Fried Potato Strips. *Journal of Food and Nutrition Sciences*, 2(4), 200. <https://doi.org/10.11648/j.jfns.20140204.26>.
- Awuchi, C., Igwe, V., & Echeta, C. (2019). the Functional Properties of Foods and Flours. *International Journal of Advanced Academic Research, Sciences*, 5(11), 2488–9849.
- Chandra, S., & Samsheer. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, 8(38), 4849–4852. <https://doi.org/10.5897/AJAR2013.6905>.
- Dey, K. C., Begum, R., Islam, M. S., Khatun, M., & Chandra Dey, K. (2015). A Study on Nutritional and Functional Properties Analysis of Jackfruit Seed Flour and Value Addition to Biscuits. *International Journal of Engineering Research & Technology*, 4(12), 139–147. www.ijert.org.
- Devi, R. (2015). Processing and Impact on Nutrition. *Scholars Journal of Agriculture and Veterinary Sciences*, 2(4A), 304–311. <https://doi.org/10.36347/sjavs.2015.v02i04.007>.
- Doijode, S. D. (2020). Jackfruit: *Artocarpus heterophyllus* Lam. In *Seed Storage of Horticultural Crops*. <https://doi.org/10.1201/9781439800072-18>.
- Ejiofor, J., E., Beleya, E. A., & Onyenorah, N. I., (2014). The Effect of Processing Methods on the Functional and Compositional Properties of Jackfruit Seed Flour. *International Journal of Nutrition and Food Sciences*, 3(3), 166. <https://doi.org/10.11648/j.ijnfs.20140303.15>.
- Falade, K. O., & Okafor, C. A. (2015). Physical, functional, and pasting properties of flours from corms of two Cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) cultivars. *Journal of Food Science and Technology*, 52(6), 3440–3448.
- Gupta, P. (2019). *Think India Journal Product Development: Snacks Prepared From Jackfruit Seed Flour and Corn Flour*. 30, 770–778.
- Hadnadev, T. D., Torbica, A., & Hadnadev, M. (2011). Rheological properties of wheat flour substitutes/alternative

- crops assessed by Mixolab. *Procedia Food Science*, 1, 328–334. <https://doi.org/10.1016/j.profoo.2011.09.051>.
- Islam, M. ., Begum, R., Khatun, M., & Dey, K. (2015). A study on Nutritional and Functional Properties Analysis of Jackfruit Seed Flour and Value Addition to Biscuits. *International Journal of Engineering Research & Technology (IJERT)*, 4(12), 139–148.
- Juárez-Barrientos, J. M., Hernández-Santos, B., Herman-Lara, E., Martínez-Sánchez, C. E., Torruco-Uco, J. G., Ramírez-Rivera, E. J., Pineda-Pineda, J. M., & Rodríguez-Miranda, J. (2017). Effects of boiling on the functional, thermal and compositional properties of the Mexican jackfruit (*Artocarpus heterophyllus*) seed Jackfruit seed meal properties. *Emirates Journal of Food and Agriculture*, 29(1), 1–9. <https://doi.org/10.9755/ejfa.2016-08-1048>.
- Noor, F. (2014). Physicochemical Properties of Flour and Extraction of Starch from Jackfruit Seed. *International Journal of Nutrition and Food Sciences*, 3(4), 347. <https://doi.org/10.11648/j.ijnfs.20140304.27>.
- Ocloo, F., Bansa, D., Boatın, R., Adom, T., & Agbemavor, W. (2010). Physico-chemical, functional and pasting characteristics of flour produced from Jackfruits (*Artocarpus heterophyllus*) seeds. *Agriculture and Biology Journal of North America*, 1(5), 903–908. <https://doi.org/10.5251/abjna.2010.1.5.903.908>.
- Pikuda, O. O., & Ilelaboye, N. O. A. (2009). Proximate composition of street snacks purchased from selected motor parks in Lagos. *Pakistan Journal of Nutrition*, 8(10), 1657–1660. <https://doi.org/10.3923/pjn.2009.1657.1660>.
- Prakash, O., Kumar, R., Mishra, A., & Gupta, R. (2009). Review Article *Artocarpus heterophyllus* (Jackfruit): An Overview. *PHCOG REV. : Review Article*, 3(6), 353–358.
- Roy Chowdhury, A., Bhattacharyya, A. K., & Chattopadhyay, P. (2012). Study on functional properties of raw and blended jackfruit seed flour (a non-conventional source) for food application. *Indian Journal of Natural Products and Resources*, 3(3), 347–353.
- Tharise, N., Julianti, E., & Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. *International Food Research Journal*, 21(4).
- Waghmare, R., Memon, N., Gat, Y., Gandhi, S., Kumar, V., & Panghal, A. (2019). Jackfruit seed: An accompaniment to functional foods. *Brazilian Journal of Food Technology*, 22, 1–9. <https://doi.org/10.1590/1981-6723.20718>.