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RESEARCH ARTICLE

DEVELOPMENT OF READY-TO-EAT BREAKFAST FLAKES WITH GREEN BANANA (*Musa acuminata*) AND JACKFRUIT SEEDS (*Artocarpus heterophyllus*) FLOUR: A COMPREHENSIVE ANALYSIS OF NUTRITIONAL AND FUNCTIONAL PROPERTIES

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ABSTRACT

Green banana flour (GBF) and jackfruit seed flour (JSF) present sustainable solutions for reducing banana waste and offering a gluten-free alternative in the food industry. The present study explores the feasibility of a composite mixture of GBF and JSF as a nutritious option for preparing breakfast flakes, evaluating their proximate composition and functional properties. The flakes were formulated with 15% JSF and varying ratios of GBF and Corn flour (w/w); T1 (50:35) T2 (60:25), T3 (70:15), T4 (80:5), and a control sample (C) with 100% corn flour. Physico-functional properties of GBF and JSF, proximate composition and antioxidant activity of the breakfast flakes were determined using standard protocols. Sensory evaluation was conducted by a semi-trained panel using a 5-point hedonic scale. The physico-functional data suggested JSF had higher water absorption (24.66±0.58%) and oil absorption (52.33±2.52%) than GBF (5.08±0.38%, 6.14±0.38%). In the sensory data, the T3 sample exhibited the highest scores for taste (4.03±0.91), texture (3.73±0.87), crunchiness (4.03±0.13), and overall acceptability (3.90±0.95). Incorporating GBF and JSF positively impacted nutritional content, with T4 showing the highest crude fibre levels (5.86±0.11%) and total ash content (2.84±0.05%). Additionally, antioxidant activity was significantly elevated ($P<0.05$) in flakes with GBF and JSF, with the highest observed in T4 (19.70±0.14%) followed by T3 (18.66±0.13). Storage study data confirmed a shelf-life of 4 weeks for the developed flake samples without added preservatives at room temperature. Therefore, the present study demonstrates the potential of GBF and JSF as a healthy alternative in the bakery industry, offering both nutritional benefits and favourable sensory properties.

Keywords: antioxidant activity, composite flour, green banana flour, jackfruit seed flour, nutritional value.

INTRODUCTION

Breakfast, often hailed as the most important meal of the day, is a crucial kick-start to our mornings (Odimegwu *et al.* 2019). However, due to hectic lifestyles, many skip breakfast or opt for ready-to-eat instant foods. The benefit of ready-to-eat breakfast food is not only that it saves time, but it also eliminates the need for food preparation. These advantages, together with the appealing flavor and crispiness of the products, contribute to their popularity (Adeoye *et al.* 2019). In this context, breakfast cereals are gaining popularity worldwide. Single-grain products, mostly corn flakes, largely dominate the current cereal market. However, these cereals may lack essential nutrients since most grain sources used in their production undergo milling to remove the germ, reducing their nutritional value in vitamin and mineral content (Rehal and

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Sharma, 2022). Conversely, researchers investigating breakfast benefits have noted that the protein intake during this meal is crucial for its advantages. Certain studies suggest that a high-protein breakfast may lower postprandial glucose levels (Xiao *et al.* 2023). However, protein-rich flours are costly and not easily accessible to developing countries due to limited local availability and the need for expensive imports (Noort *et al.* 2022). Therefore, it is essential to investigate affordable and unconventional protein sources. Utilizing jackfruit seeds as a protein-rich supplement provides a promising solution without health concerns. (Waghmare *et al.* 2019)

The jackfruit (*Artocarpus heterophyllus*) is popular in many Asian countries. Although often overlooked, jackfruit seeds have significant nutritional value, making them a viable functional food ingredient. (Ranasinghe *et al.* 2019). Jackfruit seeds contain around 22% starch, 16% protein, 3.19% fiber, polyphenols, and prebiotic compounds (Odimegwu *et al.* 2019; Van *et al.* 2023). Additionally, the protein in jackfruit seeds comprises both essential and non-essential amino acids, each contributing to its specific function (Miah *et al.* 2017). Furthermore, these seeds are abundant in dietary fiber and B-complex vitamins. Their high fiber content reduces the risk of heart disease, prevents constipation, and promotes weight loss (Waghmare *et al.* 2019). The combination of jackfruit seed flour with wheat flour and other composite flours emerges as a cost-effective alternative for bakery and confectionery products, highlighting the versatile potential of this underutilized resource (Chowdhury *et al.* 2012). Green banana flour has also been proposed for use in composite flours in the bakery industry, and regular consumption is anticipated to offer positive health effects for humans (Falcomer *et al.* 2019; Mabogo *et al.* 2021).

Banana (*Musa* sp.) is a widely cultivated fruit globally (Genitha, 2014). Despite its significance, almost 20% of banana production goes unused due to size and appearance imperfections, poor grade, or skin defects, leading to substantial post-harvest losses (Falcomer *et al.* 2019). Green bananas, known for their high starch content, have a flour composition with starch levels ranging from 61.3-76.5% and a significant fiber content of 6.3-15.5% (Juarez-Garcia *et al.* 2006). Moreover, resistant starch (17.5%), specifically resistant starch type II (RS II), in green bananas provides health benefits, including disease prevention and modulation of glycemic index, diabetes, cholesterol reduction, and weight management (Thakorlal *et al.* 2010). While several studies have investigated the use of green banana flour (GBF) in composite flour biscuits (Islam *et al.* 2014; Mabogo *et al.* 2021), exploring the incorporation of GBF in ready-to-eat breakfast cereals could be a significant opportunity to introduce bioactive compounds missing in these products. Therefore, this study aimed to investigate the feasibility of a composite blend comprising Green Banana Flour (GBF) and Jackfruit Seed Flour (JSF) as a nutritious choice for formulation of breakfast flakes, with a comprehensive analysis of their proximate composition and functional properties.

MATERIALS AND METHODS

An unripe banana cultivar of Seeni banana (*Musa acuminata*) and Jack fruit seeds (*Artocarpus heterophyllus*) was obtained from a local fair in Badulla, Sri Lanka.

Preparation of green banana flour (GBF)

The green banana flour was prepared according to Genitha (2014) with slight modifications. First, the banana fingers were peeled and sliced into 3-4 mm pieces. Subsequently, the slices were immersed in a 0.5% citric acid solution for 10 min to prevent oxidative browning. Afterwards, the banana slices were allowed to drain for 10-12 min to remove excess water. The slices were then placed in a hot air oven (GX125B, Faithful Instrument, Hebei, China) and dried at 65 °C for 6 hours. Following drying, the green banana slicers were ground into a fine powder using a home scale grinder (SF1365SM, Sanford, Dubai, UAE). The resulting powder was subsequently sieved through a 250 µm sieve for 15 min at a uniform speed. Finally, the powder was packed into 300-gauge polythene bags, sealed using a polythene sealer (300FE, DZ-260S, Haizhou Packing, Zhejiang, China), and stored in a refrigerator at 4±1°C for further use.

Preparation of jackfruit seed flour (JSF)

Jackfruit seed flour was prepared using the method described by Islam *et al.* (2015). Briefly, the seeds were soaked in water overnight and manually cleaned. The white arils of the jackfruit seeds were hand-peeled before undergoing a lye-peeling process. To remove the thin brown spermoderm covering the cotyledons, the seeds were soaked in a 3% sodium hydroxide solution for 2-3 min, then rubbed between hands and thoroughly washed with tap water. The seeds were then cut into small pieces (1-2 mm^3) and placed in a hot air oven (GX125B, Faithful Instrument, Hebei, China) at 40°C for 48 hours. After drying, the chips were powdered using a home scale grinder (SF1365SM, Sanford, Dubai, UAE) and sieved (250 µm) before being packed into 300-gauge polythene bags. The packed powder was stored in a refrigerator at 4±1°C for further use.

Evaluation of physico-functional properties of flour

The physico-functional properties of the flours were analyzed, including moisture content, flour yield, water absorption capacity, fat absorption capacity, swelling capacity and per cent of solubility of flour, and flour dispersibility. The moisture content was determined according to the AOAC standard methods. Flour yield was assessed following the process outlined by Islam *et al.* (2015) with modifications. Water absorption capacity was measured using the method described by Genitha (2014). Briefly, 10 g of flour sample was mixed with 100 mL of distilled water in a beaker, stirred for 5 minutes on a magnetic stirrer, and then centrifuged (MIKRO 200, Andreas Hettich, Berlin, Germany) at 1415×g for 30 minutes. The water absorption capacity was calculated based on the difference between the initial volume of water added (W1) and the volume of the supernatant (W2).

The oil absorption capacities of the flour samples were determined following the procedure by Mabogo *et al.* (2021). A 1 g sample was dispersed in 10 mL of refined oil, then centrifuged at 2,000g for 30 min. The oil absorption capacity was expressed as the percentage of oil bound per gram of the sample. Swelling capacity was assessed using the method outlined by Islam *et al.* (2015) with slight modifications. In brief, 250 mg of flour was weighed into a 50 mL conical tube, 10 mL of distilled water was added, and the sample was kept in a boiling water bath (YCW-012S, Gemmy Industrial Corporation, Taipei, Taiwan) at 100 °C for 30 minutes. The swelling power was calculated using the formula after cooling and centrifugation at 3500 rpm for 15 min.

$$\text{Swelling power (g/g)} = (W_1 - W_2)/W_1$$

Where, W_1, weight of the flour and W_2, weight of the suspension

For the percentage solubility of the flour, 10 mL of supernatant (Vs) was pipetted into a petri dish, and its weight was recorded (W3). The sample was dried at 105 °C until a constant weight was reached (W4). The percentage solubility was calculated using the formula below.

$$\text{Solubility}(\%) = \frac{(\text{w3} - \text{w4})}{\text{Vs}} \times \frac{100}{\text{w1}}$$

Where W_4 is the weight of the supernatant, W_3 is the weigh$_t$ of the dried supernatant, and Vs is the volume of supernatant

For flour dispersibility, 10 g of the flour sample was measured into a 100 mL stoppered measuring cylinder and topped with distilled water. The sample was shaken vigorously and allowed to stand at room temperature for 3 hours. Subsequently, the volume of settled particles was measured and subtracted from 100 to obtain the percentage dispersibility (Islam *et al*. 2015).

Preparation of the green banana and jackfruit seeds flour breakfast flakes

The composite flour mixture was prepared using jackfruit seeds flour, green banana flour,

and corn flour (as detailed in Table 1). The breakfast flakes were prepared using the method described by Abogunrin and Ujiroghene (2022). In summary, a formulated composite flour (100 g) was mixed with sugar (5 g), salt (1 g), and water (150 mL) in a mixture (SF1365SM, Sanford, Dubai, UAE). The batter was poured into a stainless-steel tray covered with baking paper and preheated on a gas stove to obtain a semi-dried product.
The semi-dried products were then cut and placed back into the oven for further drying at 150 °C for 30 minutes. Subsequently, the dried products were cooled, packed in aluminum foil, vacuum-sealed in HDPE bags, and stored at room temperature for further analysis. The flakes were formulated with 15% jackfruit seeds flour (JSF) and varying ratios of green banana flour (GBF) and corn flour (w/w): T1 (50:35), T2 (60:25), T3 (70:15), and T4 (80:5). The control sample was prepared with only 100% corn flour. The optimum proportions of JSF (15%) and the ratios of GBF to be incorporated into the composite flour mixture were determined through preliminary investigations involving sensory analysis and physicochemical testing.

Table 1: Composite flour formulation for breakfast flakes made from blends of jack-fruit seed, green banana, and corn flours (w/w)

Sample	JSF	GBF	Corn Flour
Control	-	-	100
T1	15	50	35
T2	15	60	25
T3	15	70	15
T4	15	80	5

JSF: Jack seed flour, GBF: Green banana flour

C: control sample, T1: 50% GBF and 15% JSF flour flakes, T2: 60% GBF and 15% JSF flour flakes, T3:70% GBF and 15% JSF flour flakes and T4: 80% GBF 15% JSF flour flakes

Proximate composition

The breakfast flakes and flour samples were analyzed for total solid contents, ash, protein, fat, and fiber content. The total solids content was determined by oven-drying a known weight of samples at 102°C until a constant weight was achieved. Ash content was determined using AOAC method 942.05. Total protein and fat were analyzed using the Kjeldahl method (method 991.20; AOAC, 2006) and the Soxhlet extraction method, respectively. The dietary fiber content of the samples was measured by the AOAC method 978.10 (AOAC, 2006).

Carbohydrate content was calculated by difference: Total carbohydrate = 100 - (% moisture + % ash + % fat + % protein + % crude fiber).

Organoleptic properties evaluation of breakfast flake samples

A semi-trained panel consisting of 30 members carried out sensory analysis of breakfast cereal samples to investigate the color, taste, body and texture, crunchiness, and overall acceptability of the samples. The evaluation was conducted using a five-point hedonic scale (5 for 'like very much' and 1 for 'dislike very much'). The analysis was performed according to the guidelines provided by the International Organization for Standardization (ISO, 2017).

Antioxidant activity of breakfast flakes

Methanol extracts of breakfast flakes samples were prepared using the method described by Gull *et al.* (2018). In brief, 2 g of flakes were immersed in 80% methanol extract and placed on a shaker at 150 rpm for 2-3 hours at room temperature. The mixture was then centrifuged at 1400g for 20 min, and the supernatant was decanted and utilized for antioxidant activity determination. The antioxidant activity of the methanol extracts from flake samples was determined following the method outlined by Kariyawasam *et al.* 2023). In the process, 200 µL of methanol extract was mixed with 1 mL of 100 µM DPPH and allowed to react for 15 minutes at 25 °C in the dark. The absorbance of the samples was measured at 517 nm, and the DPPH radical scavenging activity of the samples was calculated using the following formula.

$$\text{DPPH Scavenging activity(\%)} = \frac{(\text{A control} - \text{A sample})}{\text{A control}} \times 100$$

Where, A control and A sample represent the absorbance of the control (methanol) and methanol extract of the flake samples, respectively.

Shelf-life analysis of breakfast flakes

The breakfast flake samples (each pack containing 100 g of flakes) were packed in HDPE bags and labelled. These samples were stored at room temperature (28±1 °C) for 4 weeks. The moisture content was measured using a moisture analyzer (MA 110. R, Radwag, Radom, Poland), and water activity was assessed using a water activity meter (LWTM-A10, Labtron Equipment, Surrey, UK) at 2-week intervals over the 4-week storage study. Furthermore, the total plate count and yeast and mold counts of the samples were measured after the 4-week storage study by using the spread plate count method.

Statistical data analysis

Statistical analysis was conducted using SPSS Statistics 25 (IBM, USA). The data were assessed through one-way analysis of variance (ANOVA), and a significant difference was determined at a 5% significance level ($P<0.05$) using the Tukey HSD All-Pairwise Comparisons Test. The sensory data were analyzed using the Kruskal -Wallis one-way analysis of variance.

RESULTS AND DISCUSSION

Evaluation of physico-functional properties of flour

The physico-functional results of the green banana flour and jackfruit seed flour are shown in Table 2. The moisture content of green banana flour and jackfruit seed flour was 6.18±0.19% and 5.78±0.60%, respectively. These findings align with the observations by Tortoe *et al.* (2009), reporting a moisture content range of 5.1%-7.3% in green banana flour, and Noort *et al.* (2022), indicating a moisture content of 6.28%-9.16% for jackfruit seed flour. Achieving precise moisture content is crucial for ensuring consistent and desirable outcomes in the baking process.

The water absorption capacity of jackfruit seed flour (24.66±0.58%) was higher than that of green banana flour (5.08±0.38%). This difference suggests that the proteins in jackfruit seeds consist of a more hydrophilic subunit structure than GB proteins, enabling them to bind more water (Chowdhury et al. 2012). The presence of hydrocolloids and starch in jackfruit seed flour may contribute to its high water absorption, supported by findings by Odimegwu *et al.* (2019).

The oil absorption capacity (OAC) is equally important for mouthfeel and flavor retention (Islam *et al.* 2014). Jackfruit seed flour exhibited a higher fat absorption capacity (52.33±2.52%) compared to GBF (6.14±0.38%). High oil absorption suggests the hydrophobic structures of jackfruit seed protein subunits. This OAC indicates potential applications in bakery products such as cakes and cookies (Chowdhury *et al.* 2012; Mabogo *et al.* 2021).

Table 2: Physico-functional properties of green banana flour and jackfruit seed flour

Parameter	**GBF**	**JFS**
Moisture content (%)	6.18±0.19^{a}	5.78±0.60^{b}
Flour yield (%)	12.53±0.16^{a}	34.70±8.44^{b}
Water absorption capacity (mL/100g)	5.08±0.38^{a}	24.66±0.58^{b}
Fat absorption capacity (mL/100g)	6.14±0.38^{a}	52.33±2.52^{b}
Dispersibility (%)	14.83±0.76^{a}	33.83±0.76^{b}
Swelling power (g/g)	4.76±0.25^{a}	2.76±0.30^{b}
Percent solubility (%)	1.93±0.81^{a}	2.25±0.26^{a}

JSF: Jack seed flour, GBF: Green banana flour

C: control sample, T1: 50% GBF and 15% JSF flour flakes, T2: 60% GBF and 15% JSF flour flakes, T3: 70% GBF and 15% JSF flour flakes and T4: 80% GBF 15% JSF flour flakes

a-b Means within a column with different superscripts significantly differ ($P< 0.05$).

All values represent the mean values of three replicates (mean ± SD).

Dispersibility, indicative of a flour's ability to moisten without forming lumps, is vital for reconstitution ability (Otegbayo *et al.* 2013). Higher dispersibility percentages suggest the greater ability to reconstitute into a fine paste (Oulai, 2014) and indicate high water absorption capacity (Hyacinthe *et al.* 2021). GBF and JSF showed dispersibilities of 14.83±0.76% and 33.83±0.76%, respectively. The swelling power of GBF (4.76±0.25%) was higher than JSF (2.76±0.30%), suggesting stronger bonding forces within the starch granules of JSF and a potentially higher amylose lipid complex (Mabogo *et al.* 2021). Solubility, indicating the rate and extent of powder particles' component dissolution in water, was higher in JSF (2.25±0.26) compared to GBF (1.93±0.81). Due to unripe states, low solubility in GBF could be attributed to its high resistant starch content (Tribess *et al.* 2009).

Nutritional composition of breakfast flakes

The nutritional composition results of breakfast flakes are presented in Table 3. The T4 sample demonstrated the highest moisture content (4.58±0.07%) (P<0.05) which can be attributed to the incorporation of the highest quantity of composite flour mixture (80% GBF and 15% JSF). However, no statistically significant differences (P>0.05) in moisture content were observed among T1 (4.27±0.01%), T2 (4.32±0.02%), T3 (4.30±0.06), and the control sample (4.37±0.02). It is noteworthy that cereal flakes conventionally possess a moisture content ranging from 4% to 6% (Serna-Saldivar, 2016), imparting a distinct crispness under these specific moisture conditions. The addition of JSF and GBF significantly (P<0.05) increased the protein content of breakfast flakes: T1 (8.46±0.05%), T2 (8.27±0.11%), T3 (7.44±0.02), T4 (7.07±0.06), and control (6.81±0.06). This suggests the potential of a composite flour mixture of GBF and JSF to meet the protein demand of developing nations. Moreover, our results align with Odimegwu *et al.* (2019), who reported an increase in protein content in breakfast cereals made from flour blends of maize and jackfruit seeds. Other studies have also reported an increase in protein content in breakfast cereals with the addition of non-conventional flour composites, including quinoa flour flakes (7.36 to 9.46%) and defatted peanut flour flakes (10.66% to 16.98%) (Cheewapramong *et al.* 2002; Abogunrin and Ujiroghene, 2022).

The fat content of the control sample (2.59±0.12%) was significantly higher (P<0.05) than that of the treatments, while the lowest value was observed for the T4 sample (1.05±0.03%). The increasing addition of GBF and decreasing addition of corn flour lowered the fat content. This might be attributed to the lower fat absorption capacity of GBF. Islam *et al.* (2014) also reported reduced fat content in cookies with added green banana flour. The addition of a composite flour mixture of GBF and JSF had a positive impact on fibre content. All the treatment samples had significantly higher fiber contents than the control (P < 0.05). The highest fiber content was observed in T4 (5.86±0.11%), followed by T3 (4.56±0.04%). The high fiber content in composite flour

Table 3: Proximate composition of breakfast flakes

Sample	Moisture%	Protein%	Fat %	Crude fibre%	Ash %	CHO %
C	4.37 ± 0.02^{a}	6.81 ± 0.06^{a}	2.59 ± 0.12^{a}	3.62 ± 0.06^{a}	1.76 ± 0.04^{a}	80.88 ± 0.22^{a}
T1	4.27 ± 0.01^{a}	8.46 ± 0.05^{b}	1.28 ± 0.07^{b}	4.15 ± 0.10^{b}	2.04 ± 0.0^{b}	79.77 ± 0.03^{b}
T2	4.32 ± 0.02^{a}	8.27 ± 0.11^{c}	1.18 ± 0.09^{bc}	4.38 ± 0.07^{c}	2.60 ± 0.07^{c}	79.25 ± 0.23^{c}
T3	4.30 ± 0.06^{a}	7.44 ± 0.02^{d}	1.09 ± 0.02^{bc}	4.56 ± 0.04^{c}	2.71 ± 0.01^{cd}	79.90 ± 0.09^{b}
T4	4.58 ± 0.07^{b}	7.07 ± 0.06^{e}	1.05 ± 0.03^{c}	5.86 ± 0.11^{d}	2.84 ± 0.05^{d}	78.60 ± 0.98^{d}

$_{a}$-d Means within a column with different superscripts are significantly differed (P< 0.05).

All values represent the mean values of three replicates (mean ± SD).

C: Control sample, T1: 50% GBF and 15% JSF flour flakes, T2: 60% GBF and 15% JSF flour flakes, T3: 70% GBF and 15% JSF flour flakes and T4: 80% GBF 15% JSF flour flakes mixture added samples are attributed to high dietary fiber content in GBF (6.77%) (Falcomer *et al.* 2019) and JSF (2.49%) (Islam *et al.* 2015). Our results agree with previous authors who observed increasing in fiber content in cereal flakes and cookies added with JSF (Islam *et al.* 2015; Odimegwu *et al.* 2019). Moreover, Islam *et al.* (2014) and Juarez-Garcia *et al* (2006) reported an elevation of fiber content in cookies and bread made with composite GBF. Fiber is critical in maintaining digestive function, supporting gut health, and lowering disease risk (Van *et al.* 2023). Therefore, products with added GBF and JSF may be better for individuals interested in increasing their dietary fiber intake. Similarly, the composite flour mixture improved the ash content, whereas the highest was observed in T4 2.84±0.05 followed by T3 2.71±0.01 (*P*>0.05). Ash content is important in providing minerals and trace elements to the body. Therefore, GBF and JSF-added breakfast flakes can be considered a good source of minerals. Carbohydrates are also an important source of energy for the body. The carbohydrate content in breakfast flakes ranged from 78.60 – 80.88%. The value for the control sample was 80.85%, which was significantly higher (*P*<0.05).

Antioxidant activity of breakfast flakes

The antioxidant capacity of breakfast flakes was assessed using a DPPH assay (Figure 1). The substitution of composite flour has improved the antioxidant activities of breakfast flakes. Furthermore, as the rate of GBF substitution in the breakfast flakes increased, the DPPH radical scavenging activity also increased significantly (*P*<0.05). The lowest antioxidant activity was observed in the control sample (10.35±0.19%), while the highest was observed in the T4 sample (19.70±0.14%), followed by T3 (18.66±0.13%) (*P*<0.05). These findings agree with the results obtained by Van *et al.* (2023), where DPPH radical scavenging activity increased from 11.87 mgAAE/100 g to 13.20 mgAAE/100 g with an increase in the addition of JSF ratio from 10% to 40%. Additionally, Mabogo *et al* (2021) reported a rise in DPPH activity upon partial replacement of wheat flour with GBF in biscuits. Therefore, it can be demonstrated that the addition of JSF and GBF can increase antioxidant activity, with polyphenolic compounds in GBF and JSF being attributed to this elevated antioxidant activity (Lim *et al.* 2007; Van *et al.* 2023).

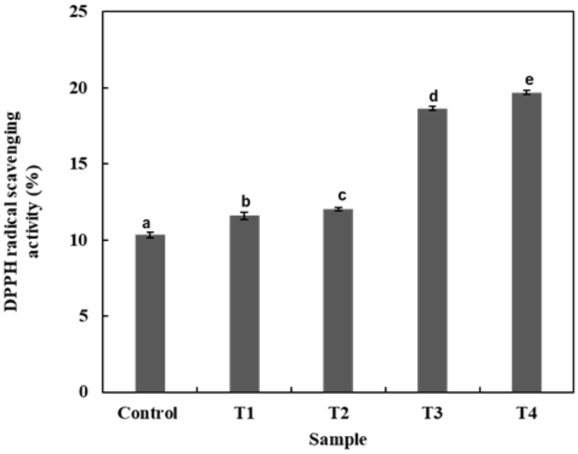

Figure 1. Antioxidant activity of breakfast flakes

a-e Means within a column with different superscripts significantly differ (*P*<0.05).

All values represent the mean values of three replicates (mean ± SD).

C: control sample; T1: 50% GBF and 15% JSF flour flakes, T2: 60% GBF and 15% JSF flour flakes, T3: 70% GBF and 15% JSF flour flakes and T4: 80% GBF 15% JSF flour flakes

Antioxidants are compounds that can delay, retard, or prevent the oxidation process. Silva *et al.* (2016) reported that a diet incorporating green banana pasta can prevent oxidative damage in the liver and kidneys and improve biochemical parameters in type 1 diabetic rats. Therefore, it can be demonstrated that the consumption of GBF and JSF has the potential to prevent oxidative stress-induced damage in humans, suggesting their potential use as functional ingredients in the food industry.

Organoleptic properties of breakfast flakes

The sensory evaluation was conducted to assess the consumer acceptability of breakfast flakes. Table 4 represents sensory evaluation data for breakfast flakes. The color of the breakfast flakes did not show a significant effect with adding GBF or JSF (*P*>0.05), as all samples had a color score ranging between

Table 4: Sensory evaluation results of breakfast flakes

Sensory attribute	Treatments				
	C	T1	T2	T3	T4
Colour	3.40±0.72^{a}	3.28±0.66^{a}	3.43±0.82^{a}	3.43±0.68^{a}	3.40±0.82^{a}
Taste	3.47±0.68^{bc}	2.83±0.70^{d}	2.93±0.64^{cd}	4.03±0.91^{a}	3.70±0.84^{ab}
Texture	3.73±0.58^{a}	3.70±0.60^{a}	3.67±0.66^{a}	3.73±0.87^{a}	3.10±0.84^{b}
Crunchiness	4.10±0.96^{a}	4.00±1.20^{a}	4.03±0.49^{a}	4.03±0.13^{a}	3.00±0.91^{b}
Overall Acceptability	3.68±0.98^{a}	3.57±0.87^{a}	3.67±0.78^{a}	3.90±0.95^{a}	3.63±1.13^{a}

a-d Means within a column with different superscripts significantly differ ($P < 0.05$).

All values represent the mean values of sensory scores (mean ± SD).

C= control sample; T1= 50% GBF and 15% JSF flour flakes, T2= 60% GBF and 15% JSF flour flakes, T3=70% GBF and 15% JSF flour flakes and T4= 80% GBF 15% JSF flour flakes.

3.43 and 3.28. The higher level of GBF improved the taste, with the highest taste score observed for T3 (4.03±0.91) (P<0.05). The lowest taste scores were reported for T1 (2.83±0.7). The reduction in taste scores might be attributed to the dominant taste of jackfruit seed flour. Van *et al.* (2023) also observed a reduction in sensory score values upon adding JSF to cookies. However, Islam *et al.* (2014) reported a decrease in flavor properties in biscuits after adding hot air-dried banana flour. The texture and crunchiness of flakes were maintained up to 70% substitution of GBF, but these properties were significantly reduced in flakes with 80% GBF, with values of 3.10±0.84 and 3.00±0.91 for texture and crunchiness, respectively (P<0.05). The highest overall acceptability value was reported for the T3 sample (3.90±0.95), followed by the control (3.68±0.98) and T2 (3.67±0.78) (P>0.05).

Based on the sensory results, the T3 formulation was selected as the best for developing breakfast flakes. It showed better taste and overall acceptability, with no adverse effects on texture, crunchiness, or color upon the substitution of GBF and JSF.

Shelf-life of breakfast flakes

The T4 sample exhibited the highest moisture content (4.58±0.07%) (P<0.05) just after production. This high moisture content may be attributed to the addition of the highest amount of GBF, which has a moisture content of 6.18%. The remaining samples had moisture content ranging between 4.27±0.01% and 4.37±0.02%, with no significant elevation observed (P>0.05). During the storage period, moisture content increased in all samples. At the end of the 4-week storage period, the moisture content of the samples was as follows: control 4.59±0.06%, T1 4.50±0.06%, T2 4.67±0.03%, T3 4.67±0.04%, and T4 4.82±0.03%. However, these moisture content values remained within the recommended range outlined by the Food (Cereals, Pulses, Legumes, and Derived Products) draft regulation, 2020.

No significant difference (P>0.05) in water activity was observed just after production, with values ranging between 0.45±0.02 and 0.43±0.01. Moreover, there were no significant differences (P>0.05) noted between the samples, except for the T2 sample (0.45±0.02), during the storage period, indicating the product's storage stability within the 4-week storage period.

The microbiology data revealed the absence of yeast and mold counts at the beginning, and Total Plate Count (TPC) values were less than 50 cfu/g in all samples, implying safety for consumption. At the end of the 4-week storage period, yeast and mold counts were less than 10 cfu/g, whereas the TPC count was 200 cfu/g. These values remained within the acceptable limit ($<10^3$) for ready-to-eat cereal groats, flakes, semolina, and whole grain products. (FAO, 2000)

CONCLUSIONS

This study demonstrates the feasibility of producing breakfast flakes through a combination of corn flour blended with Jackfruit Seed Flour (JSF) and Green Banana Flour (GBF). Both types of flours exhibit better water absorption capacity, oil absorption capacity, high dispersibility, and swelling capacity. Notably, the formulation of breakfast flakes with 15% JSF and 70% GBF resulted in the best taste and overall acceptability without any adverse effects on color, texture, or crunchiness. Furthermore, the addition of JSF and GBF elevated the nutritional properties of the corn flakes, enhancing protein, fiber, and ash content, suggesting the potential use of these flours to produce bakery products with high nutritional value. Additionally, the antioxidant activity of the flakes increased with the supplementation of composite flour mixtures. These results highlight the potential use of JSF and GBF as composite flour mixtures in the bakery industry, offering improvements in nutritional profiles, health benefits, and sensory properties.

AUTHOR CONTRIBUTION

KMGMM and MWNB designed the study. MWNB conducted the experiments. KMGMM and MWNB analyzed the data and wrote the original draft. KMGMM revised the manuscript.

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