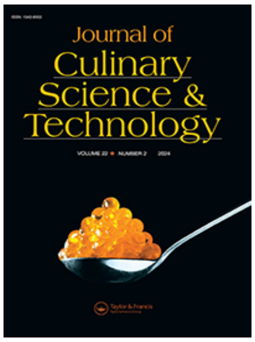

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Valorization of Jackfruit (*Artocarpus heterophllus)* Rags As a Functional Ingredient in Sandwich Cookies: Sensory, Physicochemical, and Antioxidant Properties

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ABSTRACT

The study developed sandwich cookies by substituting all-purpose flour with 0% (SC0), 10% (SC10), 20% (SC20), 30% (SC30), and 40% (SC40) of jackfruit rags flour (JRF). Sensory evaluation was conducted to analyze the consumer preference toward all sandwich cookies formulations. The proximate composition, physicochemical, and antioxidant properties of the most preferred formulation were evaluated. SC20 was the most preferred formulation with acceptable appearance, color, aroma, and texture attributes. SC20 had a significant **($p < 0.05$)** darker color than SC0 due to the incorporation of golden-brown JRF. Hardness of SC20 was significantly higher than SC0. The SC20 showed a significant increase in fiber by 2.65% compared to SC0, which meeting the requirement of high fiber claim. The DPPH scavenging activity of SC20 showed a significant increase of 14.09% as compared to SC0. JR has a great potential to be valorized into a sustainable, high fiber functional ingredient for bakery products.

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Jackfruit rags; high fiber; sandwich cookies; fruit waste; valorization

Introduction

Jackfruit, scientifically known as *Artocarpus heterophyllus*, is a fruit that grows abundantly in many tropical and subtropical regions, including Malaysia (Jashanpreet et al., 2023; Swami, Thakor, Haldankar, & Kalse, 2012). It can be divided into four major parts, namely the peel or rind, arils (ripe fruits), seeds, and rags (Frida, Tomás, & Veronica, 2021). The arils have a sweet taste, fruity aroma, and are usually consumed freshly. They can also be vacuum dried or utilized in the making of numerous products, such as jam, snacks, ice cream, and baked goods (Jashanpreet et al., 2023; Swami, Thakor, Haldankar, & Kalse, 2012). However, the rags (finger-like projections between the seeds), which comprise about 25% of the fruit weight, are generally discarded as waste. This eventually

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leads to one of the biggest economic problems and raises concerns about environmental issues (Brahma & Ray, 2022; Lim, Chin, Yusof, Yahya, & Tee, 2016). Thus, it is necessary to look for a sustainable solution to recover these fruit wastes into valuable, edible products. To date, limited studies have been done on the development of food products from the unutilized parts of jackfruit, particularly jackfruit rags (JR) (Brahma & Ray, 2022).

In fact, studies have found that JR is a rich source of protein, dietary fiber, reducing sugar, pectin, and other polyphenolics, including anthocyanins, coumarins, and flavonoids (Brahma & Ray, 2022; Dhwani et al., 2020; Jashanpreet et al., 2023). Another study by Nansereko and Muyonga (2021) also reported that JR is particularly rich in fiber (12.7%), which may contribute to positive health benefits, such as reducing the risk of cardio-metabolic diseases and colorectal cancer (Prashant, Shibani, & Aditi, 2021). Furthermore, insufficient fiber intake in the diet may affect optimal health. This could be useful data, as another study carried out by Ng, Chow, Chan, Lee, and Lim (2010) found that over 50% of Malaysian adults did not meet the daily requirement of dietary fiber as recommended in the Malaysian Recommended Nutrient Intake (RNI) for dietary fiber, which is about 20 g to 30 g per day. Inadequate intake of dietary fiber among the adults of Malaysian may be due to their eating habits or fast-paced lifestyle, which often leads to choosing fast food options that are usually lacking in fiber. Hence, this situation may be improved by incorporating JR, which contains high fiber, into an appropriate food vehicle in order to increase daily fiber intake among Malaysian adults.

Cookies are popular confectionaries that commonly consumed by individuals of all age groups across the globe (Okpala, Okoli, & Udensi, 2012). The Malaysian Adult Nutrition Survey (MANS) by the Institute for Public Health (2014) also showed that cookie is listed as the top 10 daily consumed food among Malaysians. Hence, cookies have huge market potential as nowadays consumers' food choices are driven by the convenience of food. The widespread consumption and convenience of cookies, which are in a ready-to-eat form, could be an ideal vehicle to fortify with fiber to produce a food product that allows consumers to include more dietary fiber into their daily meals, thereby meeting the recommended nutrient value (RNI) requirements (Gan, Mohd Nasir, Zalilah, & Hazizi, 2011; Norimah et al., 2008).

The incorporation of high fiber JR into cookies could deem a healthier option for consumers at the same time reintroducing edible fruit waste into the food chain, thereby reducing waste and enhancing economic value. Therefore, this study aimed to develop a nutritious sandwich cookie that meets consumers' acceptability by valorizing JR as a source of fiber.

Materials and methods

Ingredients, chemicals and reagents

Fresh jackfruits and all the ingredients used to produce the sandwich cookies including all-purpose flour, JRF, baking powder, brown sugar, salt, corn starch, low fat milk, and butter were purchased from local supermarket (Aeon, Subang Jaya, Malaysia). Boric acid, bromocresol green, ethanol, methanol, methyl red, n-hexane and sodium bicarbonate were purchased from Merck, KGaA (Darmstadt, Germany). Kjeltab catalyst tablets were obtained from Gerhardt HmbH and Co. (Königswinter, Germany). Celite 545 was purchased from FOSS (Denmark). Total dietary fiber kit (amyloglucosidase, protease and α-amylase) was purchased from Megazyme (Dublin, Ireland). 2,2-diphenyl-1-picrylhydrazyl (DPPH) and gallic acid were purchased from Sigma-Aldrich Chemical Co. (St. Louis, USA). Folin-Ciocalteu (FC) reagent, hydrochloric acid and sulfuric acids were purchased from R&M Chemicals (Selangor, Malaysia). Ultrapure water was used for the preparation of all chemical solutions.

Preparation of jackfruit rags flour

The fresh jackfruit arils and rags were separated from the rind using a ceramic knife. Vegetable oil was applied on ceramic knife to reduce the stickiness from the latex of the fruit. The JR were blanched in hot water for 2 min and cooled down in ice water bath. The excessive water was padded dry with tissue. The JR were air dried for an hour and followed by drying in baking oven (SouthStar, China) at 90°C for 8 h. Dried JR were then grinded into flour using electric grinder (Panasonic, Malaysia). The JRF was sieved to ensure consistency before kept in Schott bottle at room temperature for later use. The yield of JR and JRF was determined gravimetrically using Equations (1) and (2).

$$\textit{Yield of JR}(\%) = \frac{\text{Weight of JR(g)}}{\text{Weight of whole jackfruit(g)}} \times 100\% \quad (1)$$

$$\textit{Yield of JRF}(\%) = \frac{\text{Weighlt of JRF(g)}}{\text{Weight of fresh JR(g)}} \times 100\% \quad (2)$$

Production of jackfruit rags sandwich cookies

The sandwich cookies were developed by substituting all-purpose flour with JRF at four different percentages: 10% (SC10), 20% (SC20), 30% (SC30), and 40% (SC40). Sandwich cookies with 0% JRF (SC0) was served as control. The

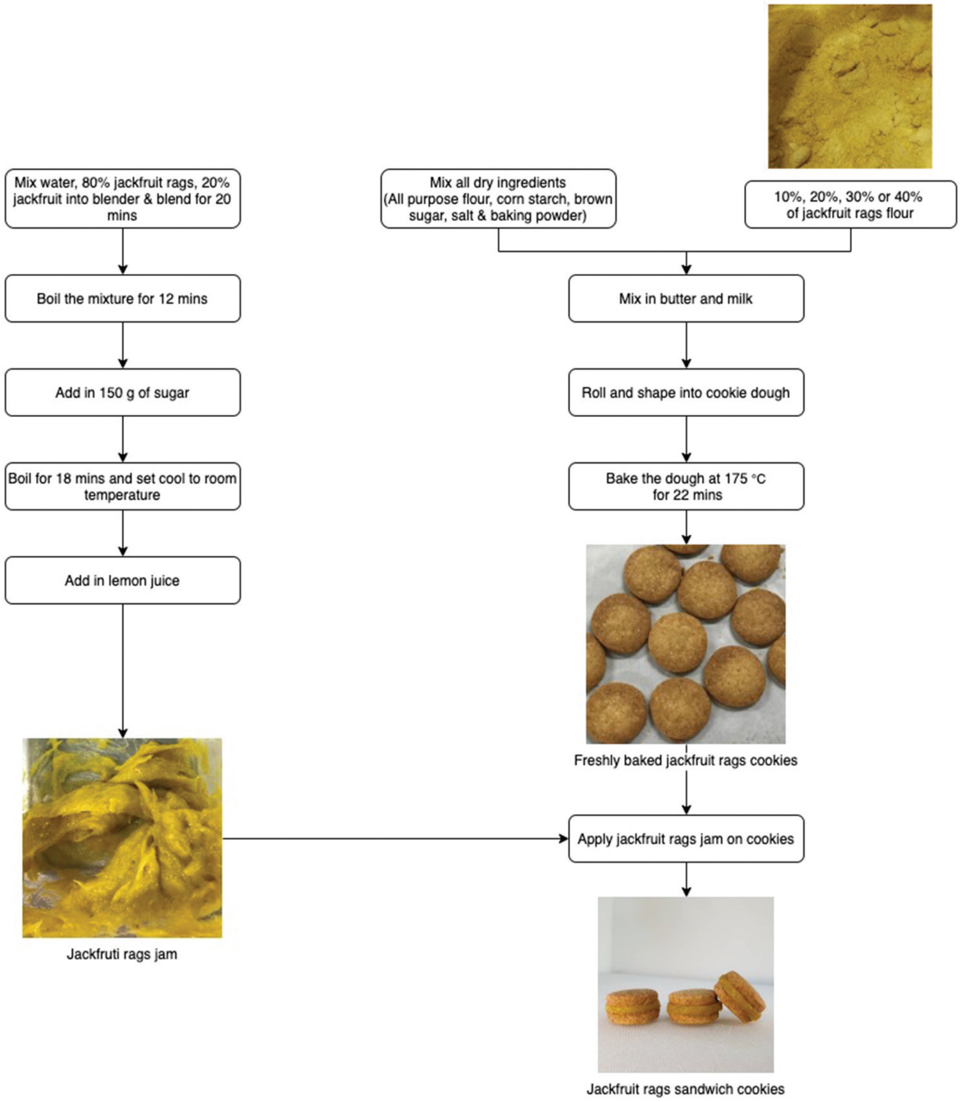

Figure 1. Production flowchart of jackfruit rags sandwich cookies (JRSC).

processing flowchart of JRSC is shown in Figure 1 while the ingredients list of the four different formulations are shown in Table 1.

Sensory analysis

Sensory evaluation of SC0, SC10, SC20, SC30 and SC40 were performed by 110 untrained panelists aged between 18 and 25 years old in Food Processing Lab, Taylor's University, under the approval of Human Ethics Committee of Taylor's University (Reference no: HEC 2017/039). The panelists were briefed about the aim of the project, and written consent was obtained from each

Table 1. Formulations of jackfruit rags sandwich cookies substituted with different percentage of jackfruit rags flour.

Ingredients (g)	SC0	SC10	SC20	SC30	SC40
All-purpose flour	90	81	72	63	54
Corn starch	18	18	18	18	18
Brown sugar	15	15	15	15	15
Salt	0.5	0.5	0.5	0.5	0.5
Baking powder	0.5	0.5	0.5	0.5	0.5
Jackfruit rags flour	0	9	18	27	36
Butter	65	65	65	65	65
Milk	15	15	15	15	15
Jackfruit rags jam	2	2	2	2	2

SC0, SC10, SC20, SC30, and SC40 represent jackfruit rags sandwich cookies substitution percentage of all-purpose flour with jackfruit rags flour at 0, 10, 20, 30 and 40% (w/w) respectively.

panelist before the sensory test began. Fresh, filtered water was provided to rest the palate between samples. The samples were labeled with 3-digit codes in random order to prevent bias. The panelists were asked to rate their degree of liking in terms of appearance, color, aroma, taste, texture, and overall acceptability for each sample based on a 9-point scale, ranging from "dislike extremely" (1) to "like extremely" (9). In the last part of the questionnaire, panelists were asked about their purchase intention for the product based on a 5-point scale, ranging from "definitely would not buy" (1) to "definitely would buy" (5).

Physical analysis

The water activity of JRSC was measured using a calibrated water activity meter (AquaLite, USA). The textural profile was analyzed using a texture analyzer (Brookfield CT3™, USA) set with a test speed of 7.00 mm/s, a load cell of 10,000 g, a trigger load of 1,000 g, and a rupture test type according to Galla, Pamidighantam, Karakala, Gurusiddaiah, and Akula (2017). A TA7 probe was used to test the hardness of JRSC. Colorimetric values were measured using a calibrated colorimeter (HunterLab, USA) with a glass optical cell. The color measurements were performed by placing the glass optical cell, evenly filled with samples, on the reflectance port to obtain the L*, a*, and b* readings.

Proximate analysis

The proximate analysis of moisture, fat, and protein in JR and JRSC was conducted using standard Association of Official Analytical Chemists (AOAC) official methods 925.10, 935.38, and 950.36, respectively (AOAC International, 2005) with slight modifications. The total dietary fiber content in JR and JRSC was determined using the enzymatic-gravimetric method, following the assay kit procedures (K-TDFR-200A, Megazyme, Ireland), where all samples were pre-dried and defatted prior to analysis. The ash content was determined according to Nielsen (2017), and the carbohydrate content was calculated by difference.

Chemical analysis

Total phenolic content (TPC)

The total phenolic content (TPC) of JR and JRSC was determined using the Folin-Ciocalteu (FC) method described by Chan, Lee, Yap, Wan Aida, and Ho (2009) with modifications. Approximately 300 µL of sample was added to 10 mL of FC reagent, and the mixture was left for 3 min before adding 0.8 mL of 7.5% (w/v) sodium carbonate. The absorbance was measured at 765 nm using a UV-Vis spectrophotometer (PerkinElmer, USA) after 2 h. Gallic acid was used as a reference standard for the calibration curve. The results were quantified as milligrams of gallic acid equivalent (GAE) per gram of sample using a linear equation derived from the gallic acid standard curve ($y = 2.2061\times - 0.048$, $R^2 = 0.9843$).

Antioxidant activity

The antioxidant activity of JR and JRSC was evaluated through DPPH radical scavenging system according to Chew et al. (2011) with slight modifications. First, 2 g of the samples were extracted by adding them to 20 mL of ethanol and incubating them in the dark at 60°C in a shaking water bath (Memmert GmbH + Co. KG, Schwabach, Germany) for 3 h. The resulting solution was then filtered using filter paper (Whatman No. 1, Sigma-Aldrich, USA). Approximately 1 mL of each sample was added with 4 mL of 0.1 mM methanolic DPPH solution and kept in the dark condition for 30 mins. Methanol was used as control assay. The absorbance was measured at 517 nm by using a UV-Vis spectrophotometer (PerkinElmer, USA) against 100% methanol as blank. The percentage of DPPH scavenging activity was calculated using the Equation (3).

$$\text{DPPH radical scavenging activity (\%)} = 1 - \frac{\text{Absorbance of sample assay}}{\text{Absorbance of control assay}} \times 100\% \tag{3}$$

Statistical analysis

The IBS SPSS 23 Inc. Software (Armonk, New York, USA) was used to analyze all data collected. The results of sensory test were analyzed using one-way analysis of Variance (ANOVA) for parametric data and Kruskal-Wallis test for non-parametric. The results of nutritional analysis were analyzed using independent t-test for parametric and Mann-Whitney for non-parametric data. The experiments were performed in triplicate of two separate runs ($n = 6$). The results of each analysis were expressed as mean ± standard deviation values with a statistically significant level of $\alpha = 0.05$.

Results and discussion

Yield

The whole jackfruit is composed of four main parts: peel or rind, arils, seeds, and rags. The yield of jackfruit rags (JR) was reported to be 10.63% per 100 g of whole jackfruit, while the yield of jackfruit rags flour (JRF) was found to be 15.30% per 100 g of fresh rag, due to water evaporation and product loss during the drying and grinding process.

Sensory evaluation

Sensory evaluation was conducted to determine the most preferred formulation of JRSC. The average hedonic scores for different percentages of JRSC are presented in Table 2. With regards to appearance, SC30 and SC40 obtained significantly lower scores ($p < 0.05$) compared to SC0 due to the substitution of high amounts of golden-brown jackfruit flour in the sandwich cookies, resulting in a dark brown final product. Additionally, visible JRF were observed on the surface of the cookies in F3 and F4, which is consistent with the color scores of the cookies, where SC40 received the lowest rating ($p < 0.05$) due to the highest percentage of JRF, resulting in the darkest color of the cookies.

In addition, there was also significant difference ($p < 0.05$) in aroma and taste scores between SC0, SC10, SC20 with SC30 and SC40 sandwich cookies.

Table 2. Sensory acceptance and purchase intention of jackfruit rags sandwich cookies substituted with different percentage of jackfruit rags flour.

	Sandwich cookies formulation				
Attributes	SC0	SC10	SC20	SC30	SC40
Appearance	6.47 ± 1.41^{a}	6.08 ± 1.35^{ab}	6.17 ± 1.30^{ab}	5.82 ± 1.62^{b}	5.67 ± 1.44^{b}
Color	6.60 ± 1.41^{a}	6.21 ± 1.22^{ab}	6.25 ± 1.37^{ab}	5.78 ± 1.64^{bc}	5.62 ± 1.53^{c}
Aroma	6.12 ± 1.39^{a}	5.95 ± 1.46^{a}	5.96 ± 1.76^{a}	5.35 ± 1.88^{b}	5.16 ± 1.58^{b}
Taste	6.61 ± 1.41^{a}	6.70 ± 1.42^{a}	6.53 ± 1.65^{a}	5.75 ± 2.03^{b}	5.61 ± 1.85^{b}
Texture	6.60 ± 1.47^{a}	6.53 ± 1.22^{a}	6.63 ± 1.56^{a}	5.83 ± 1.78^{b}	5.89 ± 1.60^{b}
Overall acceptability	6.75 ± 1.36^{a}	6.63 ± 1.33^{a}	6.54 ± 1.40^{a}	5.79 ± 1.89^{b}	5.76 ± 1.71^{b}
Purchase intention	3.61 ± 0.87^{a}	3.52 ± 0.90^{a}	3.31 ± 1.07^{ab}	3.03 ± 1.15^{bc}	2.86 ± 1.09^{c}

Sensory acceptance based on 9-point hedonic scales with descriptions: 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely. Purchase intention based on 5-point scale with descriptions: 5 = definitely would buy, 4 = probably would buy; 3 = might or might not buy, 2 = probably would not buy, 1 = definitely would not buy. Values are express in mean ± standard deviation ($n = 110$). [a-c] Mean values across same row with different superscript letter indicates significant difference by independent t-test ($p < 0.05$).

The addition of JRF may affect the aroma and taste of the cookies, which could affect the consumer acceptance toward a food product. Incorporation of 30% and 40% of JRF, respectively, were prominent to be distinguished by most of panelists, hence the average hedonic scores decreased with an increase in percentage of JRF.

The sensory test also showed that there was a significant difference ($p < 0.05$) in terms of texture between SC0, SC10, SC20, and SC30 and SC40 sandwich cookies. As the percentage of JRF increased to 30% and above, the average hedonic score decreased significantly ($p < 0.05$). This could be due to the fiber content in JRF delaying the starch gelatinization during the baking process, resulting in an increase in hardness for SC30 and SC40 cookies (Baltsavias, Jurgens, & van Vliet, 1999). Meanwhile, SC0, SC10, and SC20 were softer in texture as the starch granules have been fully gelatinized, imparting a softer texture. This also explains the higher average hedonic scores in these three samples. Based on the results, SC20 has the highest scores to satisfy consumers' expectations of texture toward sandwich cookies. Another study also reported that the preparation of bread and biscuits containing 10% and 20% of jackfruit seed flour resulted in superior color and texture (Butool & Butool, 2015).

Generally, the overall acceptability of sandwich cookies decreased with an increased percentage of JRF. However, the overall acceptability scores for SC0, SC10, and SC20 cookies were comparable ($p > 0.05$), indicating that panelists were able to accept and enjoy them. The purchase intention was highest for the control, and the scores decreased with an increased percentage of JRF in the cookies. SC10 and SC20 cookies have a higher purchase intention rating compared to SC30 and SC40 cookies, which is in agreement with the overall acceptability scores. In overall, there were no significant difference in all sensory aspects for SC10 and SC20 cookies ($p > 0.05$), suggesting that consumers accepted SC10 and SC20 cookies equally. Considering the aim of this study was to increase fiber consumption among consumers, SC20 cookie was chosen as the best formulation to be further evaluated on its physicochemical and antioxidant properties.

Physical analysis

The water activity, hardness, and color of the JRSC were examined, and the results are shown in Table 3. The water activity of SC0 and SC20 were comparable ($p > 0.05$), which were above 0.7 aw. This could inhibit the growth of microorganisms but not mold, as mold may still be able to grow at 0.7 aw or above. Besides, the water activity of JRSC was higher than typical cookies (0.3–0.4 aw), which could be due to moisture migration from jackfruit jam that affected the water activity of the sandwich cookies. Therefore, food additives, such as hydrocolloids, could be added to the sandwich cookies to improve and enhance their shelf life.

Table 3. Physical analysis of SC0 and SC20 jackfruit rags sandwich cookies.

Sample	Sandwich cookies	
	SC0	SC20
Water activity, a_w	0.77 ± 0.00^a	0.75 ± 0.02^a
Hardness, N	1199 ± 22.19^b	12946 ± 6.56^a
L*	59.66 ± 0.95^a	54.14 ± 2.37^b
a*	8.20 ± 0.04^b	9.70 ± 4.65^a
b*	30.42 ± 0.65^a	27.76 ± 0.47^b

Values are express in mean ± standard deviation ($n = 6$). $^{a\text{-}b}$Mean values of sandwich cookies across same row with different superscript letter indicates significant difference by independent t-test ($p < 0.05$).

The hardness of the sandwich cookie refers to the maximum force exerted on the sandwich cookies during the initial compression (Fujimoto et al., 2016). The force used to compress and break the sandwich cookies was significantly greater ($p < 0.05$) along with the addition of JRF, which indicated that the texture of SC20 sandwich cookies was harder compared to SC0 ($p < 0.05$). This is in alignment with the study carried out by Feili, Zzaman, Nadiah Wan Abdullah, and Tajul (2013), which showed a significant increase in crust hardness of cookies with the addition of jackfruit peel flour. In addition, another study by Ortega-González, Güemes-Vera, Piloni-Martini, Quintero-Lira, and Soto-Simental (2022) also showed that the hardness of donuts increased with the substitution of wheat flour with jackfruit seed flour due to the high amount of fiber and proteins in jackfruit seed flour. Gomez et al. (2003) reported that such hardness was resulted from the interactions between gluten and fibrous materials. The incorporation of JRF may also decrease the water content of the cookie dough and slows down the gelatinization of starch granules throughout the baking process (Baltsavias, Jurgens, & van Vliet, 1999). Consequently, majority of the starch granules were retained in the original state, leading to a harder texture (Kulp, Olewnik, Lorenz, & Collins, 1991). Furthermore, the harder texture in SC20 could also be due to a lower fat content compared to the control sample ($p < 0.05$), which constrained the development of gluten and protein hydration (Moriano, Cappa, & Alamprese, 2018).

There were significant changes in the color values (L*, a* and b*) between the SC20 and SC0 sandwich cookies ($p < 0.05$). The lightness (L*) of SC20 was significantly lower than the control due to the addition of the golden-brown color JRF during the processing step. Hence, the color of SC20 was slightly darker compared to control cookies. The higher red color intensity (a*) and lower yellow color intensity (b*) of SC20 as compared to control were also due to the incorporation of golden-brown color JRF. The darker color of SC20 sandwich cookies is consistent with the results of Ramya, Anitha, and Ashwini

Table 4. Proximate composition of jackfruit rags, SC0 and SC20 jackfruit rags sandwich cookies.

Sample	Jackfruit rags	Sandwich cookies	
		SC0	SC20
Moisture (%)	78.31 ± 0.58	14.74 ± 0.32[a]	14.48 ± 1.32[a]
Fat (%)	6.24 ± 1.43	25.18 ± 0.19[a]	23.02 ± 0.67[b]
Protein (%)	4.37 ± 0.35	1.41 ± 0.33[b]	2.19 ± 0.27[a]
Ash (%)	8.56 ± 0.22	0.88 ± 0.01[b]	1.10 ± 0.02[a]
Carbohydrate (%)	2.52 ± 0.86	57.79 ± 0.33[a]	59.21 ± 1.27[a]
Total dietary fiber (%)	37.99 ± 1.92	5.09 ± 0.91[b]	7.74 ± 0.66[a]

Values are express in mean ± standard deviation ($n = 6$). [a-b]Mean values of sandwich cookies across same row (except jackfruit rags) with different superscript letter indicates significant difference by independent t-test ($p < 0.05$).

(2020), which also showed that the addition of jackfruit peel flour caused the cookies to have a darker color than the control cookies.

Proximate analysis

The proximate analysis of JR, SC0, and SC20 sandwich cookies is presented in Table 4. The analysis of JR showed that it contains a favorable amount of nutrients such as carbohydrates, protein, and crude fiber, which could make it a useful functional ingredient (Nansereko & Muyonga, 2021; Subburamu, Singaravelu, Nazar, & Irulappan, 1992). The incorporation of JRF had a significant effect on the nutritional composition of the sandwich cookies. The fat content of a product is associated with its overall palatability as it may affect the flavor and texture of the final product (Moriano, Cappa, & Alamprese, 2018). The substitution of 20% JRF resulted in a significantly lower fat content of sandwich cookies compared to SC0 ($p < 0.05$). Similar results were seen in Ramya, Anitha, and Ashwini (2020), which showed that the replacement with jackfruit peel flour resulted in cookies with lower fat content. The lower fat content usually correlates to a lower energy content, which may be favorable for health-conscious populations (Ng et al., 2022).

The SC20 sandwich cookies displayed a significantly higher protein content than SC0 ($p < 0.05$) due to the high protein content of JR. Moreover, the incorporation of 20% JRF significantly increased the total dietary fiber content of sandwich cookies by 2.65% compared to the control owing to the high fiber content found in JR (Nansereko & Muyonga, 2021). The present study is aligning to study by Hamid et al. (2020), indicating that the meat analogue derived from jackfruit by-products (rinds, rags, and seeds) contains a higher dietary fiber when comparing with commercial meat analogue. Fibers have water-retaining properties, which are expected to increase the moisture content of cookies (Varastegani, Zzaman, & Yang, 2015). However, contrary to the expectation, present study found that incorporating 20% of JRF did not significantly impact the the moisture content of sandwich cookies. According to the Ministry of Health Malaysia

Table 5. Total phenolic content and antioxidant activity of jackfruit rags, SC0 and SC20 jackfruit rags sandwich cookies.

		Sandwich cookies	
Sample	Jackfruit rags	SC0	SC20
TPC (mg GAE/g)	0.04 ± 0.01	0.07 ± 0.00[a]	0.08 ± 0.01[a]
DPPH scavenging activity (%)	92.78 ± 0.34	41.56 ± 1.37[b]	55.65 ± 3.23[a]

Values are express in mean ± standard deviation ($n = 6$). [a-b] Mean values of sandwich cookies across same row with different superscript letter indicates significant difference by independent t-test ($p < 0.05$).

(2010), SC20 sandwich cookies could be claimed as a high-fiber food as they contain more than 6 g of fiber per 100 g of food. Therefore, it could serve as a healthier food choice for consumers.

Besides, the ash content of SC20 was significantly higher than the control due to the rich mineral content in JR ($p < 0.05$). This is also consistent with the findings of Butool and Butool (2015), who showed that biscuits made from jackfruit seed flour had a higher ash content. Jackfruit is reported to contain high levels of minerals such as potassium, iron, sodium, zinc, and calcium, which could also be the possible minerals present in JR (Swami, Thakor, Haldankar, & Kalse, 2012). Hence, the addition of 20% JRF may have indirectly contributed to the higher ash content of the sandwich cookies. The high carbohydrate content of SC0 and SC20 is comparable ($p > 0.05$) and was contributed by the addition of all-purpose flour, corn starch, and baking powder in the making of sandwich cookies (Mishra & Chandra, 2012).

Total phenolic content and antioxidant activity

The total phenolic content and antioxidant activity of JR and JRSC are shown in Table 5. The results showed that JR possessed good phenolic content and high antioxidant activity (0.04 mg GAE/g and 92.78% DPPH radical scavenging activity, respectively) due to the rich carotenoids, vitamin C, and vitamin E present in jackfruit (Swami, Thakor, Haldankar, & Kalse, 2012). The reaction between antioxidant compounds and FC reagent is used to measure the concentration of phenolic groups. A deep blue coloration in the samples thus indicates a higher concentration of phenolic compounds present (Nurliyana, Syed Zahir, Mustapha Suleiman, Aisyah, & Kamarul Rahim, 2010). The TPC of SC20 was just slightly higher than the control ($p > 0.05$). This could be due to the presence of other substances such as amines, sugar, sulfur acids, and $Fe2+$ which may interfere with the readings and lead to a false positive result (Skowyra, 2014). Similarly, the DPPH scavenging activity of SC20 was also significantly higher ($p < 0.05$) than SC0 by 14.09% due to the incorporation of JRF.

Conclusions

This study explored the value addition of agro-industrial by-products, JR, as a functional ingredient in the development of sandwich cookies. One of the major challenges faced during the production of JRSC was the collection of JR from the local groceries as the fruit waste are generally disposed together without segregation. This may indirectly lead to the increase in the production cost of JRSC since more effort is needed in ensuring the safety and usability of JR. Nevertheless, JR is a good source of fiber, nutrients, and bioactive compounds. The developed sandwich cookies had a higher fiber content, total phenolic content, and antioxidant activity than the control and exhibited good sensory characteristics. Overall, JRSC has vast potential as a healthier snack to increase the dietary fiber intake among Malaysians. Future study aspect could be focused on evaluating the feasibility of materializing JRSC into a commercial product, for example cost of production, the quality consistency and continuous supply. Furthermore, considering the concept of incorporation of food waste into food product is rather new, it is particularly essential to strengthen on the marketing and awareness of edible food waste among consumers to increase their acceptability and eliminate the stereotype of "food waste" toward such food products.

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Disclosure statement

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Credit author statement

Ching Enn, Han: Writing – Original draft preparation, Validation. **Chien Yee, Yap**: Conceptualization, Project administration, Investigation, Formal analysis. **Pei Ling, Tan**: Conceptualization, Project administration, Investigation, Formal analysis. **Dan, Lin**: Writing – Review and Editing, **Lian, He**: Writing – Review and Editing, **Chengjian, Xu**: Writing – Review and Editing, **Sook Wah, Chan**: Supervision, Writing – Review and Editing, Funding acquisition. All authors reviewed and approved the final manuscript.

References

Association of Official Analytical Chemists International – AOAC International. (2005). *Official methods of analysis* (18th ed.). Washington, USA.

Baltsavias, A., Jurgens, A., & van Vliet, T. (1999). Fracture properties of short-dough biscuits: Effect of composition. *Journal of Cereal Science*, *29*(3), 235–244. doi:10.1006/jcrs.1999.0249

Brahma, R., & Ray, S. (2022). In-depth analysis on potential applications of jackfruit peel waste: A systematic approach. *Food Chemistry Advances*, *1*, 100119. doi:10.1016/j.focha.2022.100119

Butool, S., & Butool, M. (2015). Nutritional quality on value addition to jack fruit seed flour. *International Journal of Science and Research*, *4*(4), 2406–2411.

Chan, S. W., Lee, C. Y., Yap, C. F., Wan Aida, W. M., & Ho, C. W. (2009). Optimization of extraction conditions for phenolic compounds from limau purut (*citrus hystrix*) peels. *International Food Research Journal*, *16*(2), 203–213.

Chew, K. K., Khoo, M. Z., Ng, S. Y., Thoo, Y. Y., Wan Aida, W. M., & Ho, C. W. (2011). Effect of ethanol concentration, extraction time and extraction temperature on the recovery of phenolic compounds and antioxidant capacity of *orthsiphon stamineus* extract. *International Food Research Journal*, *18*(4), 1427–1435.

Dhwani, N., Raju, G., Mathew, S. E., Baranwal, G., Shivaram, S. B. Katiyar, N., . . . Nagegowda, D. A. (2020). Antibacterial efficacy of jackfruit rag extract against clinically important pathogens and validation of its antimicrobial activity in *shigella dysenteriae* infected *drosophila melanogaster* infection model. *bioRxiv*. doi:10.1101/2020.03.09.983015

Feili, R., Zzaman, W., Nadiah Wan Abdullah, W., & Tajul, A. Y. (2013). Physical and sensory analysis of high fiber bread incorporated with jackfruit rind flour. *Food Science & Technology*, *1*(2), 30–36. doi:10.13189/fst.2013.010203

Frida, C. C. C., Tomás, G. C., & Veronica, R. M. (2021). Application of conventional and non-conventional extraction methods to obtain functional ingredients from jackfruit (*artocarpus heterophyllus* Lam.) tissues and by-products. *Applied Science*, *11*(16), 7303. doi:10.3390/app11167303

Fujimoto, K., Minami, N., Goto, T., Ishida, Y., Watanabe, M., Nagao, K., & Ichikawa, T. (2016). Hardness, cohesiveness and adhesiveness of oral moisturisers and denture adhesives: Selection criteria for denture wearers. *Journal of Dentistry*, *4*(4), 34. doi:10.3390/dj4040034

Galla, N., Pamidighantam, P., Karakala, B., Gurusiddaiah, M., & Akula, S. (2017). Nutritional, textural and sensory quality of biscuits supplemented with spinach (spinacia oleracea L.). *International Journal of Gastronomy and Food Science*, *7*, 20–26. doi:10.1016/j.ijgfs.2016.12.003

Gan, W. Y., Mohd Nasir, M. T., Zalilah, M. S., & Hazizi, A. S. (2011). Differences in eating behaviours, dietary intake and body weight status between male and female Malaysian university students. *Malaysia Journal of Nutrition*, *17*(2), 213–228.

Gomez, M., Ronda, F., Blanco, C. A., Caballero, P. A., & Apestegula, A. (2003). Effect of dietary fiber on dough rheology and bread quality. *European Food Research & Technology*, *216*(1), 51–56. doi:10.1007/s00217-002-0632-9

Hamid, M. A., Tsia, F. L. C., Okit, A. A. B., Xin, C. W., Cien, H. H. . . . Yee, C. F. (2020). The application of jackfruit by-product on the development of healthy meat analogue. *IOP Conference Series: Earth and Environmental Science*, *575*(1), 012001. doi:10.1088/1755-1315/575/1/012001

Institute for Public Health. (2014). National Health and Morbidity Survey 2014: Malaysian Adult Nutrition Survey. Vol. II: Survey Findings. 10.13140/RG.2.1.4039.9769

Jashanpreet, K., Zora, S., Hafiz, M. S. S., Muhammad, S. M., Mahmood, U. H., & Andrew, W. (2023). Insights into phytonutrient profile and postharvest quality management of jackfruit:

A review. *Critical Reviews in Food Science and Nutrition*, 1–27. doi:10.1080/10408398.2023.2174947

Kulp, K., Olewnik, M., Lorenz, K., & Collins, F. (1991). Starch functionality in cookie system. *Starch - Stärke*, *43*(2), 53–57. doi:10.1002/star.19910430205

Lim, W. J., Chin, N. L., Yusof, A. Y., Yahya, A., & Tee, T. P. (2016). Food waste handling in Malaysia and comparison with other Asian countries. *International Food Research Journal*, *23*, 1–6.

Ministry of Health Malaysia. (2010). *Malaysia Guide to Nutritional Labelling and Claims*. Retrieved March 1, 2023, from https://extranet.who.int/nutrition/gina/sites/default/filesstore/MYS%202010%20Guide%20to%20Nutrition%20Labelling%20and%20Claims.pdf

Mishra, N., & Chandra, R. (2012). Development of functional biscuit from soy flour and rice bran. *International Journal of Agriculture and Food Science*, *2*, 14–20.

Moriano, M., Cappa, C., & Alamprese, C. (2018). Reduced-fat soft-dough biscuits: Multivariate effects of polydextrose and resistant starch on dough rheology and biscuit quality. *Journal of Cereal Science*, *81*, 171–178. doi:10.1016/j.jcs.2018.04.010

Nansereko, S., & Muyonga, J. H. (2021). Exploring the potential of jackfruit (*Artocarpus heterophyllus Lam*). *Asian Food Science Journal*, *20*(9), 97–117. doi:10.9734/afsj/2021/v20i930346

Ng, S. B., Pong, Z. Y., Chang, K. A., Neo, Y. P., Chew, L. Y., Khoo, H. E., & Kong, K. W. (2022). Valorisation of mango (*Mangifera indica*) kernel as an ingredient of macaron: Sensory acceptance and physicochemical properties. *British Food Journal*, *124*(9), 2911–2920. doi:10.1108/BFJ-08-2021-0883

Ng, T. K. W., Chow, S. S. F., Chan, L. P. Y., Lee, C. Y. M., & Lim, S. Q. (2010). Recommended nutrient intake for dietary fiber; bar set too high for Malaysians? *Malaysia Journal of Nutrition*, *16*(2), 271–280.

Nielsen, S. S. (2017). *Food analysis laboratory manual* (4th ed.). New York: Springer.

Norimah, A. K., Safiah, M., Jamal, K., Haslinda, S., Zuhaida, H. . . . Azmi, M. Y. (2008). Food consumption patterns: Findings from the Malaysian Adult Nutrition Survey (MANS). *Malaysia Journal of Nutrition*, *14*(1), 25–39.

Nurliyana, R., Syed Zahir, I., Mustapha Suleiman, K., Aisyah, M. R., & Kamarul Rahim, K. (2010). Antioxidant study of pulps and peels of dragon fruits: A comparative study. *International Food Research Journal*, *17*, 367–375.

Okpala, L. C., Okoli, E., & Udensi, E. (2012). Physico-chemical and sensory properties of cookies made from blends of germinated pigeon pea, fermented sorghum and cocoyam flours. *Food Science and Nutrition*, *1*(1), 8–14. doi:10.1002/fsn3.2

Ortega-González, L., Güemes-Vera, N., Piloni-Martini, J., Quintero-Lira, A., & Soto-Simental, S. (2022). Substitution of wheat flour by jackfruit (*Artocarpus heterophyllus* lam.) seed flour: Effects on dough rheology and deep-frying doughnuts texture and sensory analysis. *International Journal of Gastronomy and Food Science*, *30*, 100612. doi:10.1016/j.ijgfs.2022.100612

Prashant, S. P., Shibani, B., & Aditi, S. (2021). Benefits of jackfruit and its natural properties to treat diabetes or colon cancer and weight loss related issues. *International Research Journal of Engineering & Technology*, *8*(3), 810–815.

Ramya, H. N., Anitha, S., & Ashwini, A. (2020). Nutritional and sensory evaluation of jackfruit rind powder incorporated with cookies. *International Journal of Current Microbiology and Applied Sciences*, *9*(11), 3305–3312. doi:10.20546/ijcmas.2020.911.395

Skowyra, M. (2014). *Antioxidant properties of extracts from selected plant materials (Caesalpinia spinosa, Perilla frutescens, Artemisia annua and Viola wittrockiana) in vitro and in model food systems* () [Doctoral dissertation, Universitat Politècnica de Catalunya]. doi: 10.5821/dissertation-2117-95555

Subburamu, K., Singaravelu, M., Nazar, A., & Irulappan, I. (1992). A study on the utilization of jackfruit waste. *Bioresource Technology*, *40*(10), 85–86. doi:10.1016/0960-8524(92)90125-H

Swami, S., Thakor, N., Haldankar, P., & Kalse, S. (2012). Jackfruit and its many functional components as related to human health: A review. *Comprehensive Reviews in Food Science and Food Safety*, *11*(6), 565–576. doi:10.1111/j.1541-4337.2012.00210.x

Varastegani, B., Zzaman, W., & Yang, T. A. (2015). Investigation of physicochemical and sensory evaluation of cookies substituted with papaya pulp. *Journal of Food Quality*, *38*(3), 175–183. doi:10.1111/jfq.12129