Sarjana International Journal of Sustainable Food and Agriculture

Journal homepage:
https://sarjanaintelek.my/index.php/sijsfa/index
ISSN: 3093-7086

The Effect of Rice and Green Banana Flours Replacement to Wheat Flour in Pumpkin Muffin on Physical Properties, Nutritional Composition and Sensory Acceptance

Norlelawati Arifin[1], Nurnasuha Siran[1,*], Rafiu Agbaje[2,3]

[1] Food Biotechnology Programme, Faculty of Science and Technology, Universiti Sains Islam Malaysia, 71800 Nilai Negeri Sembilan, Malaysia
[2] Department of Food Science and Technology, Institute of Applied Sciences, Kwara State Polytechnic, Ilorin, Nigeria
[3] Food Processing and Value Addition Programme, Centre of Excellence in Agricultural Development and Sustainable Environment, Federal Jniversity of Agriculture, Abeokuta (FUNAAB), Alabata Road, Abeokuta, Nigeria

ARTICLE INFO

Article history:
Received 18 March 2025
Received in revised form 14 April 2025
Accepted 13 May 2025
Available online 20 June 2025

Keywords:
Gluten-free pumpkin muffin; rice flour; green banana flour; xanthan gum; sensory evaluation

ABSTRACT

Muffins are popular breakfast and snack foods in many cultures around the world. Traditionally, muffins are prepared using wheat flour, which contains gluten to give a structure to the product. This study sought to fulfil the increased demand for gluten-free products by establishing the best gluten-free muffin formulation for those with celiac disease. Locally sourced ingredients such as rice flour and green banana flour to replace wheat flour to produce gluten-free products could help Malaysia lessen its reliance on imported wheat. Various rice flour and green banana flour formulations were formulated and labelled as: 75% rice flour and 25% green banana flour (75% RF: 25% GBF), 50% rice flour and 50% green banana flour (50% RF: 50% GBF), 25% green banana flour and 75% green banana flour (25% RF: 75% GBF). The effect of substituting rice flour and green banana flour on the physical qualities, nutritional content, and sensory attributes of gluten-free pumpkin muffins was studied, and pumpkin muffins made with 100% wheat flour served as a control. Gluten-free pumpkin muffins with 75% rice flour and 25% green banana flour had the greatest hardness and chewiness ratings. The viscosity of the batter muffin increased as the quantity of green banana flour increased. The 25% rice flour and 75% green banana flour formulation had the highest water activity, which corresponded to the moisture, fibre, fat, and ash contents. The crust's colour gradually darkened as the amount of green banana flour substituted rose, resulting in a drop in the yellowness (b*), redness (a*), and lightness (L*) values. The muffins with the highest dE* value were those made with the highest quantity of rice flour. According to a 9-hedonic test of sensory acceptability, gluten-free pumpkin muffins made with 50% rice flour and 50% green banana flour scored the highest out of all the gluten-free pumpkin muffins. These results demonstrated that green banana flour and rice flour could be substituted for wheat flour in pumpkin muffin formulations.

1. Introduction

* *Corresponding author.*
E-mail address: Nurnasuha.siran06@gmail.com

https://doi.org/10.37934/sijsfa.1.1.3949

Muffins are a popular breakfast or afternoon snack that is both sweet and high in calories. Consumers enjoyed the products because of their superb taste and soft texture. Muffin batter was a complicated fat-in-water emulsion prepared with an egg, sugar, water, and fat mixture. Muffins had a typical porous structure and large volume, giving them a spongy texture. A muffin recipe typically includes wheat flour, sugar, vegetable oil, eggs, and milk [1]. People with celiac disease (CD) were unable to consume this sort of baked product since it contained gluten protein. As the number of people diagnosed with celiac disease grows, so does the need for gluten-free products. Patients with celiac disease need to seek a wheat flour substitute, such as rice flour or green banana flour, because they are intolerant of the prolamins in rye, barley, and oats and the gliadin fraction of wheat [2]. Rice flour is commonly used to manufacture gluten-free items due to its bright colour, mild flavour, ease of digestion, and hypoallergenic properties [3]. Its defining characteristics are its low salt content, hypoallergenic qualities, simple digestion, bland taste, and high absorption in the human body.

Because rice flour has fewer prolamins than wheat flour, it is acknowledged as a useful ingredient in gluten-free products. It has been shown that green banana flour lowers glycaemic indices, prevents intestinal problems, and reduces inflammation. Green bananas have a high nutritional value since they are rich in antioxidants, minerals, and vitamins. They also include indigestible compounds like dietary fibre and resistant starch that may be beneficial for intestinal health [4]. Products prepared from green banana flour would have a higher amount of resistant starch than readily digestible starch than other gluten-free flours like rice and maize flour [5].

The increasing demand for gluten-free products, particularly among individuals with gluten intolerance and celiac disease, has prompted efforts to develop alternative bakery items without wheat-based ingredients. While previous studies have explored the use of composite flours such as a combination of rice flour, pumpkin flour, and green banana flour to produce gluten-free muffins [6], and the use of unripe banana flour in gluten-free rice biscuits [7], there remains limited research focusing specifically on the use of rice flour and green banana flour in varying proportions to produce gluten-free muffins. Given Malaysia's heavy reliance on imported wheat, the utilization of locally available ingredients such as rice flour and green banana flour could provide a more sustainable and cost-effective alternative. Therefore, the purpose of this study was to determine how gluten-free pumpkin muffins with varying proportions of rice flour and green banana flour could impact their physical and nutritional properties, as well as consumer acceptability.

2. Methodology

2.1 Materials

The ingredients for the gluten-free pumpkin muffin were ripe pumpkin, wheat flour (Cap Rose), rice flour (Erawan Brand), green banana flour (HealthyBhoj), sugar (CSR), eggs, salted butter, baking powder, baking soda, salt, milk (low fat Dutch Lady), xanthan gum, and vanilla essence. All ingredients were purchased from Lotus in Nilai, Negeri Sembilan, except green banana flour, which was obtained from Banamin Healthcare in India from Shopee.

2.2 Methods

2.2.1 Pumpkin puree preparation

A preheated temperature of 175°C was set for the oven. After cleaning, the pumpkin was sliced in half, and the seeds and stringy flesh were removed from the centre. The pumpkin pieces were cut into small pieces and placed on a baking pan. The pumpkin was baked until the flesh was tender, which took 45 minutes to 1 hour. Once the pumpkin has roasted and cooled down enough, the peel

was removed. After carefully dicing the flesh, it was put in a food processor. The pumpkin was processed in batches until it reached a smooth consistency, scraping down the sides as needed. To protect the samples from moisture, the pumpkin puree was kept in sealed containers for further processing.

2.2.2 Pumpkin muffin preparation

The muffin was developed with slight modifications, following Arifin *et al*., [6]. The ingredients and recipes from rice flour and green banana flour with different formulations are depicted in Table 1. Four distinct formulations of rice flour and green banana flour and control (100% wheat flour), 75% RF 25% GBF, 50% RF 50% GBF, and 25% RF 75% GBF—RF as rice flour and GBF as green banana flour were used to make gluten-free pumpkin muffins. The oven was preheated to 172 °C, and the wet and dry materials were separated. A mixture of various ratios of rice flour and green banana flour according to Table 1, xanthan gum, baking powder, and salt are among the dry ingredients that were mixed and whisked together in a big bowl. Pumpkin puree was combined with wet ingredients, which included butter, milk, eggs, sugar, and vanilla extract. After the dry and wet ingredient mixtures were ready, the wet ingredients were gradually added to the dry ingredients and thoroughly mixed. The batter was poured into three-quarters of the paper cups' space and baked at 172°C for 20 to 25 minutes in an oven. A cake tester or skewer is inserted into the middle of the muffin to check when the muffins are done baking.

Table 1
Formulations of pumpkin muffin production

Ingredients (g)	**Control**	**75% RF 25% GBF**	**50% RF 50% GBF**	**25% RF 75% GBF**
Wheat flour	**100.0**	**0.0**	**0.0**	**0.0**
Pumpkin	**45.0**	**45.0**	**45.0**	**45.0**
Green Banana Flour	**0.0**	**25.0**	**50.0**	**75.0**
Sugar	**45.0**	**45.0**	**45.0**	**45.0**
Butter	**50.0**	**50.0**	**50.0**	**50.0**
Egg	**45.0**	**45.0**	**45.0**	**45.0**
Baking powder	**4.0**	**4.0**	**4.0**	**4.0**
Salt	**0.4**	**0.4**	**0.4**	**0.4**
Milk	**40.0**	**40.0**	**40.0**	**40.0**
Xanthan gum	**0.5**	**0.5**	**0.5**	**0.5**

Keys:
Control = pumpkin muffin made with 100% wheat flour
75% RF: 25% GBF = Pumpkin muffin made with 75% Rice flour and 25% Green banana flour
50% RF: 50% GBF = Pumpkin muffin made with 50% Rice flour and 25% Green banana flour
25% RF: 75% GBF = Pumpkin muffin made with 25% Rice flour and 75% Green banana flour

2.3 Analysis
2.3.1 Physical analysis

The viscosity of muffin batter was evaluated using a Brookfield DV-II + Pro Viscometer, spindle number four (S64), and speed set at 5 rpm at room temperature (21.8 ± 2 °C) [8]. The height was determined using a ruler. The measurements were taken in triplicate on different sides of each muffin before and after baking (batter height of the baked muffin). At room temperature, 25°C, water activity was measured with an Aqualab meter. Moisture content was evaluated using the AOAC-based Oven Drying Method [9], with samples dried overnight at 105°C. The moisture content was

determined by weighing the samples and calculating the final weight. The muffins' degree of cohesiveness, chewiness, hardness, and springiness were all evaluated via the texture profile analysis utilising a Texture Analyser (Stable Micro System Ltd, Model TA-XT2i). A portable colourimeter (LabScan®XE Spectrophotometer Model, HunterLab) was used to measure the L*, a*, b*, and dE* values of the gluten-free pumpkin muffin crust's colour. A 20-gram crust of each of the muffin formulations was finely crushed and placed on a particular plate for examination [9].

2.3.2 Nutritional composition

Nutritional composition of gluten-free pumpkin muffins, such as carbohydrate, ash, fat, protein, fibre, and calorie content analyses, was carried out. The muffin was finely chopped into smaller pieces to increase the accuracy and precision of the analysis.

2.3.3 Sensory evaluation

A group of untrained volunteers as sensory panellists were asked to rate the four different formulations of muffins. The panellists were given a tray comprising a cup of fresh water and a survey, and each muffin was coded with a unique random three-digit code. Four samples were evaluated independently by 60 untrained panellists based on their preferences. Panellists were randomly chosen from the students of Universiti Sains Islam Malaysia (USIM). The sample presentation sequence was randomised to guarantee that each sample was displayed an equal number of times. Panellists were asked to score the muffins based on their visual appearance, aroma, flavour, texture, and overall acceptability. A hedonic scale (e.g., 1 = severely disliked, 9 = strongly liked) was employed for evaluation. Panellists were requested to rinse their palates with water between muffin samples to remove any residual taste.

2.3.4 Statistical analysis

The acceptability of the muffin type was determined by running statistical analyses on the data with Minitab statistical software (Version 22.2). A one-way analysis of variance (ANOVA) was used to compare physical, nutritional, and sensory data. Tukey's test was used to compare the means of the samples with 95% confidence intervals ($P < 0.05$).

3. Results

3.1.1 Physical analysis of batter viscosity of pumpkin muffin

Table 2 displays the batter viscosity in pumpkin muffins with various rice flour (RF) and green banana flour (GBF) ratios. In terms of batter viscosity, the sample with the highest GBF percentage (25% RF:75% GBF) had the highest mean value among the samples, while the control sample showed the lowest value of viscosity. There was a significant difference ($P < 0.05$) between the control group and three gluten-free pumpkin muffin samples. This suggests that green banana flour (GBF) has a higher starch content (digestible and undigestible starches) and is better at binding water, resulting in a thicker batter. The significant differences between the control and gluten-free samples in muffin formulations indicate that replacing wheat flour affects the batter's rheological features.

Table 2
Physical properties of batter viscosity for pumpkin muffin

Parameter	Control	75% RF: 25% GBF	50 % RF: 50 % GBF	25% RF: 75% GBF
Viscosity of batter (Cp)	34327.00± 1444.00^{c}	41867.00± 1295.00^{b}	43265.00± 265.00^{b}	49267.00± 879.00^{a}

Note: Superscripts within the same row with different letters are significantly different at (P<0.05)

The flour's water-binding capacity determined the viscosity of muffin batter. The "water binding capacity" refers to a flour's ability to absorb and hold water molecules. The gluten-free pumpkin muffins with the highest percentage of green banana flour (25% RF:75% GBF) achieved the highest value. Green banana flour's high-water binding capability results in a highly viscous batter, which may negatively affect product quality. The batter's viscosity is an important physical property because it directly influences the ultimate quality of the baked product. A high-quality muffin should be evenly aerated when baked. The initial batter viscosity influences air incorporation, retention, bubble stability, and convection current generation during baking. Batter viscosity is affected by the shear-thinning and thickening properties of different wheat compositions [10].

3.1.2 Physical analysis and Texture Profile Analysis (TPA) of pumpkin muffin

Table 3
Physical properties and Texture Profile Analysis (TPA) of pumpkin muffin

Parameter	Control	75% RF: 25% GBF	50 % RF: 50 % GBF	25% RF: 75% GBF
Height (cm)	2.80 ± 0.10^{a}	2.13 ± 0.15^{c}	2.37 ± 0.06^{bc}	2.57 ± 0.06^{ab}
Water Activity (aw)	0.99 ± 0.00^{a}	0.90± 0.02^{b}	0.96 ± 0.02^{a}	0.98 ± 0.01^{a}
Moisture (%)	29.71 ± 0.61^{a}	19.78 ± 0.18^{b}	21.14 ± 1.13^{b}	29.68 ± 0.85^{a}
		Texture Profile Analysis (TPA)		
Hardness (N)	49.54 ± 1.67^{a}	62.38 ± 4.89^{a}	60.32 ± 9.79^{a}	51.30 ± 33.4^{a}
Springiness (cm)	1.02 ± 0.04^{a}	0.10 ± 0.00^{a}	0.89 ± 0.10^{a}	0.95 ± 0.02^{a}
Chewiness (N/cm)	0.34 ± 0.12^{a}	0.43 ± 0.26^{a}	0.30 ± 0.03^{a}	0.29 ± 0.01^{a}
Cohesiveness (ratio)	22.77 ± 11.71^{a}	17.77 ± 5.32^{a}	24.56 ± 17.28^{a}	30.28 ± 6.35^{a}

Note: Superscripts within the same row with different letters are significantly different at (P<0.05)

Keys:
Control = pumpkin muffin made with 100% wheat flour
75% RF: 25% GBF = Pumpkin muffin made with 75% Rice flour and 25% Green banana flour
50% RF: 50% GBF = Pumpkin muffin made with 50% Rice flour and 25% Green banana flour
25% RF: 75% GBF = Pumpkin muffin made with 25% Rice flour and 75% Green banana flour

The highest height value was obtained by the control sample, followed by the sample with the highest GBF percentage (25% RF:75% GBF). It is because the combination of gliadins and glutenins in wheat flour forms a gluten network, resulting in a visco-elastic dough that retains carbon dioxide when baked, resulting in a large volume expansion [11]. Rice flour and green banana flour cannot form a gluten network because they lack gliadins and glutenins. According to Rakkar [12], the gluten-

free commercial bread prepared in the study with replacement flours such as tapioca starch and rice flour had a solid texture and minimum volume, which were not comparable to the attributes present in regular wheat bread. Additionally, the batter's viscosity may influence the final volume or height of the muffin. As previously mentioned, gluten-free muffin batter tends to have higher viscosity, which reduces its ability to retain air.

Water activity significantly influenced texture, sensory perception, and microbiological activity. The amount of available water in the system influences how big molecules interact, altering both the rheological and textural features of liquids and solids [13]. Using rice flour and green banana flour instead of wheat flour in pumpkin muffins decreased the water activity significantly ($P<0.05$) compared to the original recipe. Increasing the amount of green banana flour from 25% to 75% increased the water activity content from 0.90 to 0.98. Alivola and Monterde [7] discovered that unripe banana flour has a higher water absorption capacity of 1.82 mL/g compared to rice flour's capacity of 1.56 mL/g. As a result of the unripe banana flour's higher water absorption capacity, gluten-free pumpkin muffins produced with it had higher water activity levels than those made with rice flour. Moisture content increased as the percentage of green bananas increased. The difference in moisture content could be attributed to the lack of a gluten network in green banana flour and rice flour, resulting in more water separation during cooking. Green banana flour contains a high concentration of insoluble fibre (7.15 g/100g for peeled banana), which interacts relatively efficiently with significant amounts of water via hydroxyl groups inherent in the fibre structure [8]

There were no significant differences in hardness (N), springiness (cm), chewiness (N/cm), or cohesiveness among the four muffin formulations ($P>0.05$). Hardness is the amount of force required to create a particular deformation. Gluten-free pumpkin muffins became harder as the rice flour content increased. When the amount of rice flour in gluten-free pumpkin muffins was increased from 25% to 75%, the texture got firmer. A reduction in lipid content may cause an increase in hardness [14]. It was discovered that the muffin with 75% rice flour had the lowest fat content and the highest hardness score. Springiness refers to how quickly a product returns to its original state after being deformed.

The springiness value decreased significantly as rice flour content increased. This finding was consistent with a study from [15], in which 100% green banana flour had the highest springiness value of 0.858cm, compared to composite flour and wheat flour, which were 0.761 cm and 0.853 cm, respectively. Chewiness is a measurement of the amount of energy required to bite through solid food and convert it into a swallowable form [16]. It increased significantly ($P<0.05$) when the rice flour ratio increased. Cohesiveness measures the amount of energy required to chew the meal piece, as well as the sensory crumbliness and impressions of the muffin's density [17]. The highest cohesiveness ratio was obtained by 25% RF:75% GBF muffin. Based on observations, muffins with larger proportions of green banana flour broke easily during handling.

3.1.3 Colour analysis of pumpkin muffin

Table 4 displays the colour profile of pumpkin muffins. The brightness parameter ranged from 0 (dark) to 100 (white), a* from 100 (green) to 100 (red), and b* from 100 (blue) to 100 (yellow) [18]. The hues of gluten-free pumpkin muffins were altered by the type and formulation of flour used in the research. The colour characteristics of the gluten-free pumpkin muffin and the control pumpkin muffin differed. The sample control, prepared from 100% wheat flour, showed the highest significant value ($P<0.05$) in all parameters: 66.78 for L*, 8.21 for a*, 53.70 for b*, and 56.64 for dE*.

Table 4
Colour analysis of pumpkin muffins

Parameter	Control	75% RF: 25% GBF	50% RF: 50 %GBF	25% RF: 75% GBF
				
Crust Lightness (L)*	66.78 ± 0.17[a]	42.39 ± 0.12[b]	39.13 ± 1.06[c]	35.23 ± 0.59[d]
Crust Redness (a)*	8.21 ± 0.07[a]	6.80 ± 0.09[b]	6.11 ±0.02[c]	6.40± 0.33[bc]
Crust Yellowness (b)*	53.70 ± 0.42[a]	25.65 ± 0.21[b]	21.24± 1.01[c]	17.97 ± 0.58[d]
dE*	56.64 ± 0.42[a]	26.52 ± 0.23[b]	23.33 ± 1.19[c]	22.64 ± 0.58[c]

Note: Superscripts within the same row with different letters are significantly different at (P<0.05).

Keys:
Control = pumpkin muffin made with 100% wheat flour
75% RF: 25% GBF = Pumpkin muffin made with 75% Rice flour and 25% Green banana flour
50% RF: 50% GBF = Pumpkin muffin made with 50% Rice flour and 25% Green banana flour
25% RF: 75% GBF = Pumpkin muffin made with 25% Rice flour and 75% Green banana flour

Colour influences consumer acceptability, making it an important food quality indicator. The colour of the flour is important because it affects the hue of the finished product [19]. The 25% RF: 75% GBF muffin had a brownish tone and a lower yellow highlight, making it appear considerably darker. The 25% RF: 75% GBF muffin was the darkest, with a deep brown crust, indicating a considerable colour shift due to the higher GBF concentration. The lowest L*, a*, and b* values were 25% RF and 75% GBF. The hue of the raw material utilised, such as flour, affected the crust colour value; green banana flour was darker than rice flour. In addition, pumpkins are a great source of β-carotene, the precursor of vitamin A that gives them their yellow or orange colour. Then, through the chemical processes of caramelisation and the Maillard reaction, sugar contributed to browning, which darkened the muffins' colour. For all four muffin samples, the crust's dE* value was $\Delta E^* > 6$, indicating a significant difference. Similar results were obtained by [7], who showed that the addition of unripe banana flour at 80% and 100% produced a darker (lower L* value), less reddish (lower a* value), and less yellowish (lower b* value) colour. When cookies were made using 0% to 100% unripe banana flour, the L* value decreased from 27.00 to 16.98, the b* value decreased from 20.96 to 11.62, and the a* value decreased from 7.80 to 5.27. As the quantity of unripe banana flour substituted increased, the findings of the investigation by [7] revealed a similar pattern of less vibrant and darker colour profiles.

3.2 Nutritional Composition

Table 5 shows the nutritional makeup of pumpkin muffins, including ash, protein, fat, carbohydrate, fibre, and calorie content. The control pumpkin muffin made with 100% wheat flour

had considerably lower (P<0.05) amounts of ash, fibre, and carbohydrate, but greater levels of protein, fat, and calories compared to the gluten-free pumpkin muffin made with a mix of rice and green banana flour.

Table 5
Nutritional composition of pumpkin muffin

Parameter	Control	75% RF:25% GBF	50% RF:50% GBF	25% RF:75% GBF
Ash (%)	1.64 ± 0.11^{c}	1.88 ± 0.01^{b}	2.05 ± 0.04^{b}	2.29 ± 0.08^{a}
Protein (%)	6.47 ± 0.07^{a}	4.93 ± 0.02^{b}	4.62 ± 0.28^{bc}	4.30 ± 0.03^{c}
Fat (%)	21.98 ± 4.58^{a}	10.45 ± 2.19^{b}	11.86 ± 0.73^{b}	17.27 ± 2.87^{ab}
Fibre (%)	0.39 ± 0.17^{c}	0.69 ± 0.06^{b}	0.84 ± 0.06^{b}	1.18 ± 0.03^{a}
Carbohydrate (%)	41.76 ± 5.63^{b}	62.95 ± 2.01^{a}	60.33 ± 1.98^{a}	46.46 ± 2.86^{b}
Calorie (kcal/100g)	384.50 ± 23.70^{a}	360.16 ± 13.17^{a}	366.55 ± 1.01^{a}	358.46 ± 15.27^{a}

Note: Superscripts within the same row with different letters are significantly different at (P<0.05).

Keys:
Control = pumpkin muffin made with 100% wheat flour
75% RF: 25% GBF = Pumpkin muffin made with 75% Rice flour and 25% Green banana flour
50% RF: 50% GBF = Pumpkin muffin made with 50% Rice flour and 25% Green banana flour
25% RF: 75% GBF = Pumpkin muffin made with 25% Rice flour and 75% Green banana flour

The ash content of a product shows its mineral index. The gluten-free pumpkin muffin made with the highest proportion of green banana flour had the highest ash concentration. According to Anggraeni and Saputra [20], unripe banana flour had 1.02% ash, which was significantly more than the 0.58% found in wheat flour for dry noodles. It showed that banana flour has a higher mineral level. Furthermore, Rahman *et al*., [21] observed that adding banana flour to wheat flour bread formulations increased the amount of ash, indicating that incorporating more banana flour increases mineral components.

The highest mean protein content of a gluten-free pumpkin muffin was 75% RF:25% GBF, which declined significantly as the amount of green banana flour increased. A similar tendency was discovered by Jauharah *et al*., [14], who reported that protein content reduced when green banana flour was added to muffins. The value of protein formed with wheat flour was 9.37, composite flour (rice flour and green banana flour) was 9.03, and 100% green banana flour was 8.57. Aside from that, it was consistent with Arifin et al. 2024 [6], who found that increasing the amount of rice flour added to the gluten-free muffin from 16.66g to 50.01g increased the crude protein level from 6.12 to 6.92. The fat content of gluten-free pumpkin muffins varied, with 75 RF:25% GBF having the lowest and 25% RF:75% GBF having the highest. Statistical analysis revealed no significant difference (P<0.05) in fat content among the gluten-free pumpkin muffins, but a significant difference (P>0.05) between the control and three gluten-free muffins.

The fibre content of gluten-free pumpkin muffins made with rice and green banana flour increased when compared to the control sample. The substitution of 25% to 75% green banana flour resulted in a significant rise in fibre [22]. Also discovered that increasing the concentration of unripe

banana flour in the formulation boosted the fibre content of the cookies. By increasing from 15g to 50g of unripe banana flour in the muffins, the dietary fibre content increased dramatically from 6.6 to 10.9.

The highest percentage, 62.95, was found in the carbohydrate content of gluten-free pumpkin made with 75% rice flour. As the proportion of rice flour increased, so did the carbohydrate content. Because of the high fibre content, the calorie content dropped as the proportion of green bananas rose. This result was consistent with [23], which demonstrated that formulations with a higher proportion of green banana flour had lower calorie values for gluten-free chocolate chip muesli bars. Specifically, in the 100% green banana flour formulation, the calorie counts per serving size (37 g) decreased from 158 kcal to 148 kcal.

3.3 Sensory Evaluation

The results showed that the mean values scored by the panellists for appearance, colour, texture, aroma, aftertaste and overall acceptance attributes. The sample with 75% RF:25% GBF received the highest score after control for appearance, texture and aroma, while 50% RF:50 % GBF received the highest score after control for colour, after taste and overall acceptance. The results of the sensory acceptance analysis also showed that compared with other formulations, including the control, muffins with 25% RF:75 % GBF received the lowest score for all sensory attributes. Consumers did not prefer gluten-free pumpkin muffins made with a high percentage of green banana flour, probably due to its texture, which was overly dense and did not match the expectations of consumers who prefer the fluffy structure, and due to its offered health benefits, which were high in fibre and resistant starch, which affected the taste, which was grassy or slightly sweet, making it less appealing to consumers. Significant differences ($P<0.05$) were identified in overall acceptance between the control muffin and alternative formulations containing rice flour and green banana flour.

Table 6
Sensory evaluation of pumpkin muffin

Sensory attribute	Control	75% RF: 25% GBF	50 % RF: 50 % GBF	25% RF: 75% GBF
Appearance	6.95 ± 1.62^{a}	6.77 ± 1.45^{ab}	6.72 ± 1.32^{ab}	6.20 ± 1.73^{b}
Colour	7.00 ± 1.73^{a}	6.58 ± 1.62^{a}	6.60 ± 1.51^{a}	6.25 ± 1.78^{a}
Texture	6.87 ± 1.74^{a}	6.27 ± 1.67^{ab}	6.22 ± 1.61^{ab}	$5.55^{d} \pm 1.69^{b}$
Aroma	6.53 ± 1.95^{a}	6.47 ± 1.81^{a}	6.40 ± 1.60^{a}	6.15 ± 1.66^{a}
After taste	6.90 ± 1.54^{a}	6.48 ± 1.81^{ab}	6.62 ± 1.54^{ab}	6.05 ± 1.91^{b}
Overall Acceptance	6.90 ± 1.43^{a}	6.53 ± 1.61^{ab}	6.60 ± 1.51^{ab}	5.95 ± 1.92^{b}

Note: Superscripts within the same row with different letters are significantly different at ($P<0.05$).

Keys:
Control = pumpkin muffin made with 100% wheat flour
75% RF: 25% GBF = Pumpkin muffin made with 75% Rice flour and 25% Green banana flour
50% RF: 50% GBF = Pumpkin muffin made with 50% Rice flour and 25% Green banana flour
25% RF: 75% GBF = Pumpkin muffin made with 25% Rice flour and 75% Green banana flour

The highest rating was given for the appearance of gluten-free muffins prepared with 75% RF: 25% GBF by the panellists. It was discovered that as the amount of rice flour increased, so did the appearance score. This could be related to the muffin's outer layer, as consumers may prefer a higher percentage of rice flour, which has a lighter and smoother texture than a higher percentage of green banana flour. The panellists preferred the hue for gluten-free pumpkin muffins made with 50% RF

and 50% GBF. The greatest texture value for gluten-free muffins was 75% RF:25% GBF (6.27), while the lowest was 25% RF:75% GBF (5.55). This demonstrated that adding additional green banana flour to gluten-free muffins resulted in an unappealing texture. This was consistent with the hardness of the muffins as evaluated by a Texture Profile Analyser (TPA) (Table 3). In contrast to the study by Alviola *et al*., [7], Jauharah *et al*., [14], the substitution of green banana flour for rice flour at 70% and above showed a significant improvement ($P<0.05$) in the score of crumb texture, which became hard.

There was no significant difference ($P > 0.05$) in the aroma attribute between the four muffin samples. As the ratio of green banana flour increased, the average aroma score decreased. This could be attributed to the green banana flour's strong 'earthy aroma', as the substitution amount increased from 25% to 75%. The overall acceptance of all four sample pumpkin muffins differed significantly ($P > 0.05$) from the control and three gluten-free pumpkin muffin samples. This suggested that replacing wheat flour with rice flour and green banana flour had a significant ($P> 0.05$) effect on the overall acceptability of these muffins. Since all of the gluten-free muffins in this study received scores of more than 4, which were 6.53, 6.60 and 5.95, the sensory panellists considered them to be acceptable [24].

4. Conclusions

Substituting rice flour and green banana flour for wheat flour in gluten-free pumpkin muffins significantly increased batter viscosity, hardness, and cohesiveness ($P<0.05$). Wheat flour replacement with gluten-free flour in pumpkin muffins boosted ash, fibre, and carbohydrate percentage while decreasing protein, fat and calorie contents. These nutritional data revealed that gluten-free pumpkin muffins were more nutritious than those made with regular wheat flour. Gluten-free pumpkin muffins baked with a composite flour ratio of 50% rice flour and 50% green banana flour had the highest overall acceptability score (6.6) following the control. These findings suggested that rice flour and green banana flour can efficiently replace wheat flour in muffin recipes, which makes it suitable for celiac disease patients while also reducing reliance on imported wheat flour by using local ingredients such as green banana flour and rice flour. Hence, recommendations for future research on gluten-free pumpkin muffin properties include optimising the ratio of rice flour and green banana flour in gluten-free muffins using response surface methodology and using grated green bananas treated with an anti-browning agent to mitigate the negative effect on colour and appearance.

Acknowledgement

The authors would like to express their deepest gratitude to the Faculty of Science and Technology, Universiti Sains Islam Malaysia, for their financial support.

References

[1] Ureta, María Micaela, Daniela F. Olivera, and Viviana O. Salvadori. "Quality attributes of muffins: Effect of baking operative conditions." *Food and Bioprocess Technology* 7 (2014): 463-470. https://doi.org/10.1007/s11947-012-1047-7

[2] Wongklom, P., P. Chueamchaitrakun, and N. Punbusayakul. "Effect of xanthan gum/CMC on bread quality made from Hom Nil rice flour." *International Food Research Journal* 23, no. 5 (2016): 2300.

[3] Ronie, M. E., and M. Hasmadi. "Factors affecting the properties of rice flour: a review." *Food Res* 6, no. 6 (2022): 1-12. https://doi.org/10.26656/fr.2017.6(6).531

[4] Ho, L. H., T. Nur Hasyimah, and A. L. Amira Nadia. "Nutritional compositions, physicochemical properties, and sensory attributes of green banana flour-based snack bar incorporated with konjac glucomannan." *Food Research* 6, no. 2 (2022): 128-138. https://doi.org/10.26656/fr.2017.6(2).275

[5] Radünz, Marjana, Taiane Mota Camargo, Camila Francine Paes Nunes, Elisa Dos Santos Pereira, Jardel Araújo Ribeiro, Helen Cristina Dos Santos Hackbart, Amanda Fabres Oliveira Radünz, André Luiz Radünz, Márcia Arocha Gularte, and Fabrizio Da Fonseca Barbosa. "Gluten-free green banana flour muffins: chemical, physical, antioxidant, digestibility and sensory analysis." *Journal of food science and technology* 58 (2021): 1295-1301. https://doi.org/10.1007/s13197-020-04638-5

[6] Arifin, Norlelawati, Arwa Karimah Muhammad Nasir, and Agbaje Rafiu. "Gluten-Free Muffin: Effect of Composite Flours (Rice, Pumpkin and Unripe Banana) on The Physicochemical Properties and Sensory Attributes." *International Journal of Advanced Research in Food Science and Agriculture Technology* 2, no. 1 (2024): 31-39. https://doi.org/10.37934/fsat.2.1.3139

[7] Alviola, Juma Novie A., and Viena G. Monterde. "Physicochemical and Functional Properties of Wheat (Triticum aestivum) and Selected Local Flours in the Philippines." *Philippine Journal of Science* 147, no. 3 (2018).

[8] Bezerra, Carolina Vieira, Antonio Manoel da Cruz Rodrigues, Edna Regina Amante, and Luiza Helena Meller da Silva. "Nutritional potential of green banana flour obtained by drying in spouted bed." *Revista Brasileira de Fruticultura* 35 (2013): 1140-1146. https://doi.org/10.1590/S0100-29452013000400025

[9] Horwitz, William. "Official Method of Analysis. Association of Official Analytical Chemists, Arlington, VA, USA (2000).

[10] Sakiyan, Ozge, Gulum Sumnu, Serpil Sahin, and Goknur Bayram. "Influence of fat content and emulsifier type on the rheological properties of cake batter." *European Food Research and Technology* 219 (2004): 635-638. https://doi.org/10.1007/s00217-004-1020-4

[11] Mariotti, Manuela, Mara Lucisano, M. Ambrogina Pagani, and Perry KW Ng. "The role of corn starch, amaranth flour, pea isolate, and Psyllium flour on the rheological properties and the ultrastructure of gluten-free doughs." *Food Research International* 42, no. 8 (2009): 963-975. https://doi.org/10.1016/j.foodres.2009.04.017

[12] Rakkar, Pardeep Singh. "Development of a gluten-free commercial bread." *Master of Applied Science thesis, Department of Food Science, Auckland University of Technology, Auckland* (2007).

[13] Lewicki, Piotr P. "Water as the determinant of food engineering properties. A review." *Journal of food engineering* 61, no. 4 (2004): 483-495. https://doi.org/10.1016/S0260-8774(03)00219-X

[14] Jauharah, MZ Anis, WI Wan Rosli, and S. Daniel Robert. "Physicochemical and sensorial evaluation of biscuit and muffin incorporated with young corn powder." *Sains malaysiana* 43, no. 1 (2014): 45-52.

[15] Kaur, Kamaljit, Gurinderpal Singh, and Navdeep Singh. "Development and evaluation of gluten free muffins utilizing green banana flour." *Bioved* 28, no. 2 (2017): 359-365.

[16] Peleg, Micha. "The instrumental texture profile analysis revisited." *Journal of Texture Studies* 50, no. 5 (2019): 362-368. https://doi.org/10.1111/jtxs.12392

[17] Sanz, T., Ana Salvador, Raquel Baixauli, and S. M. Fiszman. "Evaluation of four types of resistant starch in muffins. II. Effects in texture, colour and consumer response." *European Food Research and Technology* 229 (2009): 197-204. https://doi.org/10.1007/s00217-009-1040-1

[18] Ly, Bao Chau K., Ethan B. Dyer, Jessica L. Feig, Anna L. Chien, and Sandra Del Bino. "Research techniques made simple: cutaneous colorimetry: a reliable technique for objective skin color measurement." *Journal of Investigative Dermatology* 140, no. 1 (2020): 3-12. https://doi.org/10.1016/j.jid.2019.11.003

[19] Alviola, Juma Novie A., and Viena G. Monterde. "Physicochemical and Functional Properties of Wheat (Triticum aestivum) and Selected Local Flours in the Philippines." *Philippine Journal of Science* 147, no. 3 (2018).

[20] Anggraeni, R., and Dede Saputra. "Physicochemical characteristics and sensorial properties of dry noodle supplemented with unripe banana flour." *Food Research* 2, no. 3 (2018): 270-278. https://doi.org/10.26656/fr.2017.2(3).061

[21] Rahman, Towhidur, Shompa Akter, Ashfak Ahmed Sabuz, and Rahmatuzzaman Rana. "Characterization of wheat flour bread fortified with banana flour." *International Journal of Food Science and Agriculture* 5, no. 1 (2021). https://doi.org/10.26855/ijfsa.2021.03.002

[22] Agama-Acevedo, Edith, José J. Islas-Hernández, Glenda Pacheco-Vargas, Perla Osorio-Díaz, and Luis Arturo Bello-Pérez. "Starch digestibility and glycemic index of cookies partially substituted with unripe banana flour." *LWT-Food Science and Technology* 46, no. 1 (2012): 177-182. https://doi.org/10.1016/j.lwt.2011.10.010

[23] Protopapas, V. B., S. Bhaduri, and K. Navder. "Comparison of the physical, textural, sensory, and nutritional properties of rice flour and green banana flour on the acceptability of gluten-free chocolate chip oatmeal bars." *Journal of Food Processing & Technology* 11, no. 12 (2021): 856.

[24] Feili, R., Wahidu Zzaman, Wan Nadiah Wan Abdullah, and Tajul A. Yang. "Physical and sensory analysis of high fiber bread incorporated with jackfruit rind flour." *Food Science and Technology* 1, no. 2 (2013): 30-36. https://doi.org/10.13189/fst.2013.010203