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Gluten-Free Muffin: Effect of Composite Flours (Rice, Pumpkin and Unripe Banana) on The Physicochemical Properties and Sensory Attributes

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ABSTRACT

Muffins are popular breakfast or snack items and are enjoyed in various cultures around the world. It is typically sweet and can come in various flavours such as blueberry, chocolate chip or banana nut. It is one among numerous baked items frequently crafted using wheat flour. However, individuals with gluten-related diseases such as celiac disorder and gluten intolerance are unable to consume wheat flour. In this research, gluten-free muffins made with a composite flour of rice, pumpkin and unripe banana with different ratios F1 (1:1:1), F2 (3:2:1), F3 (2:1:3) and F4 (1:3:2) were applied. The gluten-free muffins prepared with F3 (2 rice: 1 pumpkin: 3 unripe banana) composite flour showed the highest values of springiness and chewiness among all the samples. The gluten-free muffins using F2 (3 rice: 2 pumpkin: 1 unripe banana) composite flours were the highest for lightness and b* yellowness values. In addition, these muffins also obtained the highest percentages for ash and crude fiber contents. The 9-point scale hedonic test showed that consumers' preferences for gluten-free muffins with a ratio of 2 rice: 1 pumpkin: 3 unripe banana flours (F3) were the highest in scores as compared to the other gluten-free muffins. Thus, the study suggested that F3 which contains 2 rice: 1 pumpkin: 3 unripe banana flours was selected as the best formulation to make gluten-free muffins.

1. Introduction

Muffin is a very well-known batter-based bakery product that is widely consumed by all the generations in the world today. Muffins are made from wheat flour, sugar, fat, eggs and baking powder without the need of yeast or require incubation time for dough like bread. So, muffins can also be said to contain gluten since they are made with wheat flour. Gluten plays a crucial role in the baking process and has several important functions in baked products. It is used in baked products for better texture, flavour and moisture retention since it is heat resistant and acts as a binding and extending agent [1]. However, some people have gluten-related disorders, such as celiac disease or non-celiac gluten sensitivity which requires them to avoid gluten-containing food. For those

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individuals, alternative gluten-free flours and binders can be used to achieve similar textures without the use of gluten in baked products.

Rice flour is one of the good composite flours for making gluten-free products since it lacks gluten and contains low sodium, fat and protein levels [2]. It also has a bland taste, and white colour, and is highly digestible with hypoallergenic properties [3]. Recently, pumpkin flour was highlighted in baking products as a main ingredient since it is rich in nutrients including carotenoids, Vitamin A, Vitamin C, Vitamin E and omega-3 fatty acids. Mala *et al.,* [4] mentioned that pumpkin flour is widely used in bakery products because of its highly desirable flavour, sweetness and deep yellow-orange colour. Unripe banana flour presents itself as potentially viable flour in the development of gluten-free products probably due to its high level of resistant starch. Resistant starch does not break down in the small intestine and arrives unchanged at the colon producing short-chain fatty acids (SCFAs) [5]. Additionally, bananas also contain vitamin A, vitamin B, vitamin C, phosphorus, potassium, magnesium, selenium and iron [6].

This study aimed to replace wheat flour with gluten-free composite flour of rice, pumpkin and unripe banana flours in muffin formulations. Physical properties, nutritional composition and sensory acceptability were studied to determine the effect of different ratios of rice, pumpkin and unripe banana flours on gluten-free muffins. Another similar concept studied was [7] which developed gluten-free biscuits using composite flour from cassava flour and cowpea flour. Other than that, there was also a development of cookies using rice-chickpea composite flour that was formulated by [8]. To date, no gluten-free muffin formulations have been studied using the composite flour of rice, pumpkin and unripe banana flours.

2. Methodology

2.1 Materials

Rice flour (Jati rice flour), pumpkin (Cucurbitaceae family), unripe Berangan bananas (*Musa acuminata colla*) and other ingredients used in muffin production such as (baking powder, salt, white sugar, egg, milk and butter) were purchased from Lotus's supermarket in Nilai, Negeri Sembilan, Malaysia. All the chemicals and reagents used were of analytical grade.

2.2 Methods

2.2.1 Pumpkin and unripe banana flour preparation

The pumpkin was washed thoroughly with tap water and cut in half to remove the seeds and fibres while unripe Berangan bananas were removed from the bunches and washed with potable water. Afterwards, pumpkin and unripe banana were peeled and sliced into 0.2 cm using the stainless-steel knife. For sliced banana, they were then promptly rinsed in a 0.3 % weight/volume citric acid solution to prevent enzymatic browning. The temperature of the dehydrator was set to around 52 °C, and the sliced pumpkin and banana were left to dry for approximately 8-12 h until they became brittle and dry. Dried pumpkin and banana were ground into a fine powder. Then, both powders were sieved using a sieve with 100 nm mesh screen and the flours collected were kept in airtight plastic packaging to preserve the samples from external humidity.

2.2.2 Preparation of gluten-free muffin

The muffin was prepared according to Rahman *et al.,* [9] with slight modifications. The ingredients and recipes included composite flour with four different ratios, as specified in Table 1. Gluten-free muffins were prepared using four different ratios of each composite flour and the samples were identified as F1 (1:1:1), F2 (3:2:1), F3 (2:1:3) and F4 (1:3:2) of rice, pumpkin and unripe banana flours. Firstly, eggs and sugar were blended for 2 minutes or until the sugar dissolved. Cooking oil and milk were then added and mixed thoroughly. Composite flour, salt and baking powder were added and mixed well. The batter was poured into muffin cups, filling about half of the cup or 19.5 grams. The muffin cups were arranged on a baking tray and baked for 20 mins at 160 ˚C in a preheated oven. The muffins were left to cool at room temperature for 1 h on a rack to avoid moisture condensing on their under-surface.

Table 1
Ingredient formulation for gluten-free muffin production

Ingredients (gram)	F1(1:1:1)	F2 (3:2:1)	F3 (2:1:3)	F4 (1:3:2)
Rice flour	33.33	50.01	33.33	16.66
Pumpkin flour	33.33	33.33	16.66	50.01
Unripe banana flour	33.33	16.66	50.01	33.33
Sugar	35	35	35	35
Butter	50	50	50	50
Whole egg (1)	1	1	1	1
Baking powder	4	4	4	4
Salt	0.4	0.4	0.4	0.4
Milk	25	25	25	25

Note: The composite flour ratio used consisted of rice, pumpkin and unripe flours, respectively

2.3 Analysis
2.3.1 Physical analysis

Texture profile analysis of the gluten-free muffin was conducted using a Texture analyser (Stable Micro System Ltd, Model TA-XT2i). The muffins were horizontally cut at the cup's height, with the lower half (2.5 cm) used for texture measurements, and the top half discarded. A double compression test was performed with a flat-ended cylindrical probe (P/75) having a diameter of 75 mm. The test was conducted to a height of 1.25 cm (50 % compression) at a speed of 1 mm / sec, with a waiting period of 5 sec between rounds. The muffin samples were evaluated for hardness, cohesiveness, springiness and chewiness. Colorimeter (LabScan®XE Spectrophotometer Model, HunterLab) and the L*a*b* colour scale system were used to determine and analyse the crumb of gluten-free muffins' colour. Each muffin (20 g) was ground and placed into a particular plate for analysis.

2.3.2 Nutritional composition

Nutritional composition analysis (proximate analysis) includes moisture, total ash, crude fat, crude protein, carbohydrate, fibre and calorie contents. For this analysis, the muffin was chopped first into a fine particle to increase the size dimension. Moisture and ash contents were determined using methods of the Association of Official Analytical Chemists (AOAC) [10]. Moisture content was determined using the oven drying method by measuring the weight difference of the muffin before and after drying at 105˚C overnight. While, the method used for dry ashing method, involving incineration at high temperatures typically 600°C, was accomplished in a muffle furnace. The crude protein content of the gluten-free muffin was determined using the Kjeldahl method, involving three main steps: digestion, neutralization/distillation and titration; and approximately 2 gram of sample was used in the analysis. The crude fibre content of the gluten-free muffin was determined using the

Gerhardt method. The fat content of the gluten-free muffin was determined using the Soxtherm Extraction Unit (Gerhardt, Germany). The carbohydrate content in the gluten-free muffin was determined by calculating the percentage remaining after all the other components had been measured. The caloric value of the gluten-free muffin was determined in triplicate by indirect calorimetry. The calculation was based on the conversion factors of each nutrient: protein (4 kcal/g), fat (9 kcal/g) and carbohydrate (3.75 kcal/g).

2.3.3 Sensory evaluation

The sensory evaluation of the gluten-free muffin was conducted with 60 panellists, including students and staff from the Universiti Sains Islam Malaysia (USIM), Nilai, Malaysia. The panels evaluated the gluten-free muffin using a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). The muffins were cut into square shapes and given a three-digit random code for identification. The samples were provided to the panellists in separate booths with white light and at room temperature on a white plate. Portable water was provided to the panellists for mouth rinsing between tastings of each sample. Each sample was rated for appearance, colour, texture, aroma, sweetness and overall acceptability.

2.3.4 Statistical analysis

All the data were analysed using one-way analysis of variance (ANOVA). Data were calculated in triplicates. This analysis was conducted *via* the software Minitab to determine a significant difference at $p < 0.05$. Subsequently, Tukey's test was employed to compare the difference between means of values.

3. Results and Discussion

3.1 Physical Properties

Gluten is the main structure-forming protein that contributes to the viscoelasticity properties of dough or batter. Texture profile analysis is crucial to determine the effect of gluten-free composite flours on muffin formulations. The instrumental texture profile analysis of gluten-free muffins made from composite flours of rice, pumpkin and unripe banana is shown in Table 2. Muffin with F2 was found to have significantly ($p < 0.05$) the highest hardness value (217.19 N) among all the samples. An increase in hardness value for this sample was probably due to the highest rice flour content incorporated in the gluten-free muffin formulation. This result was aligned with [11] which reported that the gluten-free muffin with the highest rice flour incorporation showed the highest hardness values. On the other hand, muffins with F1 showed the lowest hardness values (109.70 N) %. The presence of high fibre in pumpkin (3.36 %) [12] and unripe banana flours (14.5 %) [13] was suggested to influence the hardness values of gluten-free muffins.

Cohesiveness represents the strength of internal bonds and indicates how much a substance can deform before it ruptures [14]. Muffins that have higher cohesiveness is deemed preferable, as it forms a cohesive bolus rather than disintegrating during chewing, whereas muffins with low cohesiveness tends to crumble easily. Among the tested formulations, the gluten-free muffins with a ratio of 1:3:2 (F4) exhibited the highest cohesiveness followed by muffins prepared with a ratio of 2:1:3 (F3). This implied that F4 and F3 muffins are less prone to crumbling and possess a more structurally sound texture compared to other formulations.

Table 2
Texture profile analysis (TPA) value of gluten-free muffins produced from rice, pumpkin and unripe banana flours

Formulation	F1(1:1:1)	F2 (3:2:1)	F3 (2:1:3)	F4 (1:3:2)
Texture Profile Analysis				
Hardness (N)	109.70^b ± 15.26	217.19^a ± 16.92	118.07^b ± 12.55	128.93^b ± 15.74
Cohesiveness (N)	0.16^b ± 0.01	0.16^b ± 0.02	0.24^a ± 0.01	0.25^a ± 0.02
Springiness (N)	0.86^b ± 0.02	0.76^c ± 0.02	0.97^a ± 0.02	0.73^c ± 0.02
Chewiness (N)	13.71^b ± 0.87	22.11^a ± 4.02	28.18^a ± 4.01	28.15^a ± 2.63
Colour				
L* (lightness)	45.92^c ± 0.05	51.09^a ± 0.02	47.68^b ± 0.21	42.59^d ± 0.12
a* (redness)	15.95^d ± 0.02	15.80^c ± 0.05	13.74^d ± 0.04	16.81^a ± 0.02
b* (yellowness)	45.78^b ± 0.43	48.90^a ± 0.87	38.11^c ± 0.53	39.99^c ± 0.29

Note: Values are means ± SD (standard deviation) of triplicate determinations. Means on the same row with different superscripts are significantly different at $p < 0.05$. The composite flour ratio used consisted of rice, pumpkin and unripe flours, respectively

Cohesiveness represents the strength of internal bonds and indicates how much a substance can deform before it ruptures [14]. Muffins that have higher cohesiveness is deemed preferable, as it forms a cohesive bolus rather than disintegrating during chewing, whereas muffins with low cohesiveness tends to crumble easily. Among the tested formulations, the gluten-free muffins with a ratio of 1:3:2 (F4) exhibited the highest cohesiveness followed by muffins prepared with a ratio of 2:1:3 (F3). This implied that F4 and F3 muffins are less prone to crumbling and possess a more structurally sound texture compared to other formulations. Conversely, the gluten-free muffins with equal levels of the three flours (F1) and those prepared with F2 displayed insignificantly lower cohesiveness values suggesting that these muffins are more susceptible to crumbling, indicating a potential issue with their structural integrity. The likely explanation for the observed differences in cohesiveness could be attributed to the inhomogeneity of the flour mixtures and variability in particle sizes, moisture content, or other factors in the flour blends.

Springiness refers to how quickly a product returns to its initial state once the force causing deformation is no longer applied [15]. Gluten-free muffin with F3 was observed as the highest mean score for springiness probably due to high fibre content. Kaur *et al.,* [15] findings were also in agreement with the present study as the researchers reported that the highest springiness values were observed in muffins with the highest amount of green banana flour as compared to its composite flour (rice flour and green banana flour with ratio 1:1).

Chewiness can be described as the energy needed to chew solid food until it transforms into a readily swallowable, simple and soluble product [16]. Gluten-free muffins with the highest value of unripe banana flour were the chewiest. This finding was quite similar to the study of [14], who found that bread made from green banana flour had the highest chewiness with a value of 5.52. According to Radünz *et al.,* [17], the omission of gluten hinders carbon dioxide retention, adversely affecting muffin quality, while the substitution of green banana flour promotes enhanced expansion and elasticity. From this perspective, the enhancement of expansion and elasticity was very related to the chewiness of the muffins.

The colour values of gluten-free muffins produced from composite flours of rice, pumpkin and unripe banana are presented in Table 2. The highest lightness (L*) value (51.09) was observed in gluten-free muffins with the highest amount of rice flour (F2). The decrease in L* values shows that gluten-free muffins had darker colours at higher levels of pumpkin flour and unripe banana flour incorporation. The darker colour of gluten-free muffins could be influenced by factors such as the combination of ingredients, air velocity in the baking oven, and the formation of brown pigments through the Maillard reaction. The lighter colour in gluten-free muffins with a high proportion of rice flour may also be associated with the white colour of the rice flour itself.

However, the redness (a*) values of gluten-free muffins showed the opposite trend. The gluten-free muffins with the lowest lightness (L*) got the highest value for redness (a*). Results in this study agreed with the findings by [18] on muffins produced using pumpkin flour. The b* value of gluten-free muffins was significantly different ($p < 0.05$) with the increment of the combination rice and pumpkin flour. Saliman *et al.,* [19] indicated that the alteration occurred because of the vibrant orange hue derived from the β-carotene in the pumpkin, which persisted in the flour even after undergoing processing.

3.2 Nutritional Composition

The nutritional composition of gluten-free muffins produced from composite flours of rice, pumpkin and unripe banana is presented in Table 3. The variations in nutritional values found in this study could be ascribed to variations in the chemical components of the individual flours employed in creating the composite flour formulation. The highest value for moisture content was found in the gluten-free muffin with equal levels of the three flours (F1). Moisture plays a role in both the mechanical and qualitative aspects of the product, impacting factors such as the gelatinization of starch in the mass during baking and influencing crispness [17].

Table 3
Nutritional composition of gluten-free muffins produced from rice, pumpkin and unripe banana flours

Formulation	F1 (1:1:1)	F2 (3:2:1)	F3 (2:1:3)	F4 (1:3:2)
Moisture (%)	22.85^{a} ± 9.50	18.042^{a} ± 0.16	19.27^{a} ± 0.52	21.55^{a} ± 0.84
Ash (%)	2.47^{b} ± 0.02	2.22^{c} ± 0.08	2.23^{c} ± 0.02	2.99^{a} ± 0.06
Crude protein (%)	6.59^{b} ± 0.02	6.92^{a} ± 0.02	6.12^{d} ± 0.02	6.45^{c} ± 0.02
Crude fibre (%)	1.80^{a} ± 0.41	1.55^{a} ± 0.24	1.72^{a} ± 0.65	2.34^{a} ± 0.17
Crude fat (%)	23.71^{a} ± 0.18	23.18^{b} ± 0.29	22.28^{b} ± 0.92	21.33^{b} ± 1.38
Carbohydrate (%)	45.95^{a} ± 9.58	50.67^{a} ± 0.46	51.05^{a} ± 1.18	48.86^{a} ± 1.45
Calorie (kcal/g)	423.50^{a} ± 0.39	439.13^{a} ± 0.04	429.18^{a} ± 0.13	412.85^{a} ± 0.18

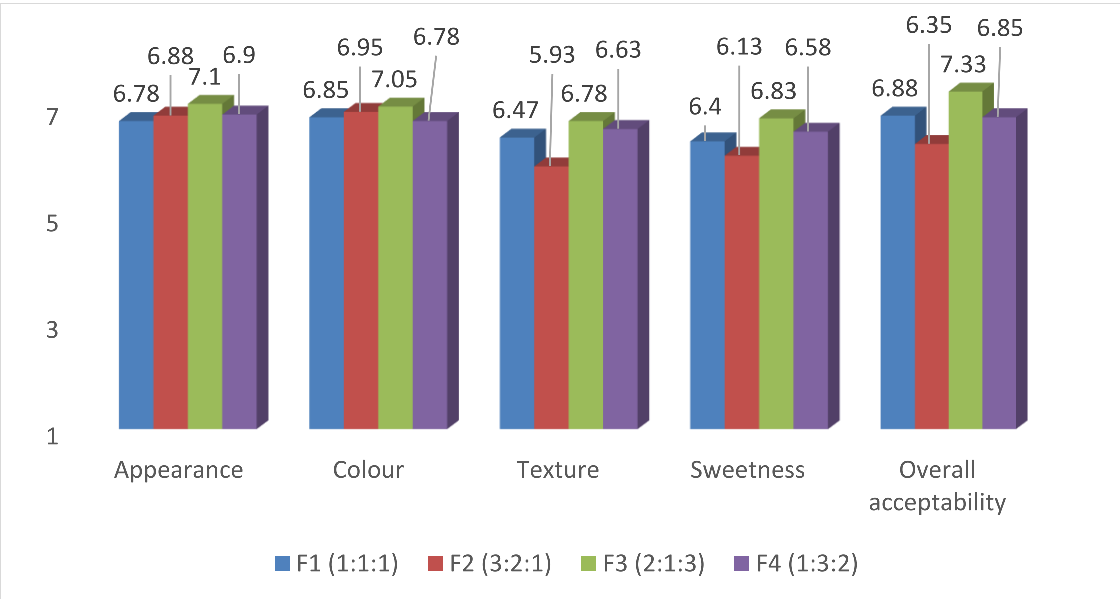
Note: Values are means ± SD (standard deviation) of triplicate determinations. Means on the same row with different superscripts are significantly different at $p < 0.05$. The composite flour ratio used consisted of rice, pumpkin and unripe flours, respectively

The ash content of a food sample is the index of the mineral elements of such food products. The muffin prepared with F2 (the highest amount of rice flour) had the lowest value while the highest value was possessed by the muffin prepared from F4 (the highest amount of pumpkin flour). This indicated that rice flour would contribute the least mineral elements to the gluten-free muffin than the other two flours. These results were in agreement with the reports by [20] where the result indicated that cookies with 70 % rice flour contain the lowest ash. The carbohydrate content was not shown significantly different ($p > 0.05$) in values with gluten-free muffins with 16.66 g of pumpkin flour (F3) obtained the highest percentage. On the other hand, the lowest value was found for muffins with the highest level of pumpkin flour which was 33.33 g (F4). These findings were similar to those obtained by [18] in their study where muffins with pumpkin flour had higher dietary fibre with a proportional reduction of the carbohydrates.

The crude protein content of the gluten-free muffin increased with the increment of rice flour incorporation. The results were in agreement with the reports by [20] that indicated the cookies made from improved protein content could be produced from rice flour. This observation could be due to higher contents of protein in rice flour relative to pumpkin and unripe banana flour. Gluten-free muffins produced with highest level of rice flour (F2) recorded the highest caloric value. The observation was similar with the past research studies by [16] that showed the sample of gluten-free chocolate chip oatmeal bar with 100 % rice flour had higher calories than samples with green banana flour. These results could be due to the higher starch content of rice flour compared to fruits like pumpkin and unripe banana flour where its easily digestible starches quickly release glucose, raising blood sugar and contributing more to calorie intake.

3.3 Sensory Evaluation

The results showed that the mean values scored by the panellists for appearance, colour, texture and sweetness attributes were not statistically different ($p > 0.05$) among the muffins produced from the three different composites of flour which were rice, pumpkin and unripe banana flour (Figure 1). For these attributes, muffin with F3 was found to be rated with the highest scores (> 6). The sensory attributes of appearance and taste play a crucial role in influencing the overall appeal and acceptance of food products [21]. In addition, the mean scores for the overall acceptability of F3 also showed a significant difference ($p < 0.05$) in value as compared to the other formulations. These results indicated that muffins produced from the composite flour with the highest level of unripe banana flour (F3) were the most preferred gluten-free muffins. The results were similar to [15] with the incorporation of green banana flour in gluten-free muffins. Meanwhile, gluten-free muffins with the highest level of rice flour (F2) in the formulation had the lowest score in terms of texture, sweetness and overall acceptability. The lowest scores obtained for these muffins might be due to the bland taste of rice flour.



Note: Means on the same row with different superscripts are significantly different at $p < 0.05$. The composite flour ratio used consisted of rice, pumpkin and unripe flours, respectively.

Fig. 1. Mean sensory values of gluten-free muffins produced from rice, pumpkin and unripe banana flour

The colour for gluten-free muffins prepared with F2 and F3 composite flours were the most preferred by the panellists. This finding was in agreement with [4] where the colour of the product was notably impacted when the substitution of pumpkin powder exceeded 20 %, with more pronounced adverse effects. Similar to the appearance and colour, the texture attribute of gluten-free muffins with F3 obtained the highest scores. The findings revealed that the panellists' favourite was the gluten-free muffin with higher levels of unripe banana flour, and this could be influenced by the appealing characteristics found in the banana flour when combined with other ingredients in the process of making muffins. Similar results were reported by [22] on the biscuits supplemented with unripe banana flour.

The correlation study showed that overall acceptance scores were highly correlated with texture attributes ($R^2 = 0.89$) and sweetness ($R^2 = 0.96$). The relationship of overall acceptability and texture was also determined using a texture analyser and a coefficient value of 0.84 was obtained. The correlation study showed that texture (sensory evaluation and instrument) is the important parameter that affects the overall acceptability of gluten-free muffins produced in this study. Surprisingly, panellists were not influenced by the colour scores to rate overall acceptability attributes as they obtained low correlation values ($R^2 = 0.32$).

4. Conclusions

The highest ratio of rice flour incorporated into the gluten-free muffins resulted in a harder texture and lighter colour. On the other hand, the percentage of pumpkin flour did not impact the b* values. The various ratios of rice, pumpkin and unripe banana flours employed in gluten-free muffin formulations significantly influence their nutritional composition except for moisture, crude fibre, carbohydrate and caloric value. For sensory acceptance, gluten-free muffins made with a composite flour ratio of 2:1:3 (rice: pumpkin: unripe banana, F3) were rated as the most acceptable sample with an overall acceptability score of 7.33. These results concluded that the replacement of wheat flour with composite flour of rice, pumpkin and unripe banana with different ratios in the formulation of muffins was an effective way to produce gluten-free muffins that would be suitable to cater for people with celiac diseases.

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