

Effect of Gluten Free Flours on Sensory Properties of 'Banana Blossom Keropok Lekor'

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DOI: <https://doi.org/10.30880/ekst.2025.05.02.039>

Article Info

Received: 1 January 2025

Accepted: 10 January 2025

Available online: 19 December 2025

Keywords

Gluten-Free, *Keropok Lekor*, Banana Blossom, Arrowroot Flour, Sweet Potato Flour, Taro Flour

Abstract

Keropok lekor is a well-known fish-based traditional dish that originated in Terengganu, Malaysia. It is typically cooked by either boiling or frying and is known for its unique and chewy texture. Unlike the traditional version made with fish, this *keropok lekor* uses banana blossom as the main ingredient, with a fibrous structure resembling meat fibre, making it an excellent plant-based alternative while offering distinctive flavour and texture. This study aims to develop a new version of *banana blossom keropok lekor* by including various gluten-free flours. The objective is to evaluate the nutritional composition, physical properties, and sensory perceptance of the *banana blossom keropok lekor* with improved nutritional value while addressing the challenges of creating non-allergic and vegan-friendly alternatives. Formulations containing sweet potato starch, taro flour, and arrowroot flour are used to enhance the nutritional profile of *banana blossom keropok lekor*. The cooked *banana blossom keropok lekor* will be boiled, cooled to ambient temperature, vacuum-sealed, stored at -18°C for further analysis. This study will evaluate the nutritional composition, physical properties, and sensory attributes of the product, focusing on the impact of substituting wheat flour with gluten-free alternatives, aiming to develop a healthier and more nutritious snack that is gluten-free, allergen-free, lower in calories, and higher in dietary fiber compared to traditional *keropok lekor*.

1. Introduction

Keropok lekor is a traditional Malaysian snack, typically made from fish, sago flour, tapioca starch, and various flavour enhancers [1]. Flour or starch acts as a filler, providing structure and allowing the *keropok lekor* to expand and achieve its crispy texture. Starch, is an excellent raw material for customizing food consistency and texture, contains varying amounts of amylose and amylopectin, influencing properties such as gelatinization and water absorption [2]. Arrowroot flour, for example, contains 29.4% amylose, while sweet potato and taro contain 26.8% and 17.3%, respectively [3]. These starches, derived from plants such as sweet potato, taro, and arrowroot, offer high fiber content and low-calorie benefits, making them viable gluten-free alternatives to wheat [4][5]. Such ingredients are significant for individuals with celiac disease (CD), a disorder affecting up to 1-2% of the population globally [6]. CD is a genetic condition where the consumption of gluten leads to malnutrition and diarrhoea [7]. Therefore, gluten-free flours, like those from sweet potato, taro, and arrowroot, are essential alternatives for managing CD and other gluten sensitivities.

Gluten intolerance is rising in Malaysia, driving a growing demand for gluten-free products. This trend has sparked increased interest in exploring the potential of gluten-free foods such as *banana blossom keropok lekor*, a variant of the traditional snack made using banana blossom instead of fish. Banana blossoms offer a unique texture and flavour, making the snack suitable for those seeking a vegan or gluten-free option [8]. However, the impact of different gluten-free flours on the sensory qualities of *banana blossom keropok lekor* remains under-researched, with most studies focusing on wheat-based formulations [9]. This gap presents an opportunity to investigate how gluten-free flour influences the taste, appearance, texture, and overall acceptability of this traditional snack.

This study aims to develop *banana blossom keropok lekor* by replacing wheat flour with gluten-free flours like sweet potato flour, taro flour, and arrowroot flour. It also analyses their effects on the product's physicochemical and sensory properties. This research seeks to enhance the nutritional profile of *keropok lekor* by using gluten-free flour, which is higher in fiber and lower in calories. By evaluating these attributes, this research intends to offer a healthier and more inclusive alternative to the traditional *keropok lekor*, catering to individuals with gluten sensitivities and those seeking healthier snack options.

2. Methodology

2.1 Materials

Banana blossom *Musa acuminata balbisiana* cultivars (BBBc) species, gluten-free flour (sweet potato starch, taro flour, and arrowroot flour) was used. The ingredients were purchased from the local market.

Table 1 Formulation 1 for 'Gluten-free *banana blossom keropok lekor*' produced with different types of flour

Ingredients/ Measurements (g)	Wheat Flour (Control) (WF)	Sweet Potato Flour (SPF)	Taro Flour (TF)	Arrowroot Flour (AF)
Banana Heart	150	150	150	150
Wheat Flour	270	-	-	-
Sweet Potato Flour	-	270	-	-
Taro Flour	-	-	270	-
Arrowroot Flour	-	-	-	270
Tapioca Flour	270	270	270	270
Oyster Mushroom	57.5	57.5	57.5	57.5
Grated Coconut	57.5	57.5	57.5	57.5
Potato	230	230	230	230
Baking Powder	6	6	6	6
Salt	19.22	19.22	19.22	19.22

Table 2 Formulation 2 for 'Gluten-free *banana blossom keropok lekor*' produced with different types of flour

Ingredients/ Measurements (g)	Wheat Flour (Control) (WF)	Sweet Potato Flour (SPF)	Taro Flour (TF)	Arrowroot Flour (AF)
Banana Heart	150	150	150	150
Wheat Flour	270	-	-	-
Sweet Potato Flour	-	270	-	-
Taro Flour	-	-	270	-
Arrowroot Flour	-	-	-	270
Tapioca Flour	270	270	270	270
Potato	230	230	230	230
Baking Powder	6	6	6	6
Salt	19.22	19.22	19.22	19.22

2.1.1 Gluten-Free Banana Blossom Keropok Lekor Processing

The method for making banana blossom *keropok lekor* consisted of first cleaning the banana heart. The tough outer layers were peeled and discarded. The stem end was cut off and the outer bracts were removed until the tender inner layers were reached, and the banana heart was cut into small pieces. Next, the banana heart was soaked in a salt solution for 30 minutes and then rinsed thoroughly under running water to remove any dirt or debris. The banana heart was then boiled for 30 minutes and rinsed with water in three separate batches. The banana heart was then pureed using a blender.

The wheat starch was substituted with gluten-free flour, i.e., sweet potato starch, arrowroot flour, and taro flour. Then, the ingredients were mixed together: banana heart, grated coconut, oyster mushrooms, and potatoes. The mixture was transferred into a mixing bowl and kneaded together with tapioca flour, baking powder, and salt.

The mixture was divided into three separate batches for each formulation, and gluten-free flour was used for each batch: sweet potato starch, arrowroot flour, and taro flour, respectively. In addition to these batches, a control batch of banana blossom *keropok lekor* was prepared using wheat starch for comparison. After kneading, the mixture was carefully formed into the desired size and rolled into a sausage-like shape 1.5 cm in diameter and 5 cm in length. The rolled and shaped *keropok lekor* was preboiled in 100°C water for 10 minutes until it floated, according to a standard method for processing *keropok lekor* [1].

The *keropok lekor* was then drained and cooled in ice water for a minute. A sharp tool was used to examine the inside of the dough to ensure that the starch was gelatinized. The cooked *keropok lekor* was then cooked again at 100°C for 10 minutes and the excess water was poured off. The boiled *keropok lekor* was placed on trays and allowed to cool to room temperature for 10 minutes [32]. Each *keropok lekor* was packed in a vacuum-sealed package and stored in a freezer at -18°C until further analysis [33]. Meanwhile, the thawed *keropok lekor* samples were deep-fried in vegetable oil at 180°C for 3 minutes, then cooled at room temperature for 5 minutes and used for physical analysis and sensory evaluation [33].

2.2 Physicochemical Properties Analysis

2.2.1 Moisture Content

A moisture analyser (A & D, MX-50, USA) was used to determine the percentage of moisture content of each gluten-free 'banana blossom *keropok lekor*' following [12] recommendations. The plate was calibrated first, 2 grams of each sample was put in the provided pan inside the moisture analyser and distributed evenly, heated for 20 minutes at 200 degrees Celsius.

2.2.2 Colour

A portable spectrophotometer (HunterLab MiniScan EZ 4500, USA) with the colour system CIE (L*a*b*) was used to determine the colour of each gluten-free 'banana blossom *keropok lekor*'. The colour of the cooked *keropok lekor* will be indicated by lightness level (L*), redness level (a*) and yellowness level (b*) [10].

2.2.3 pH

A pH meter (SX751 Model pH/DO/ORP/Conductivity Meter, San-Xin, Cao He Jing, Shanghai) was used to measure the pH of each gluten-free 'banana blossom *keropok lekor*'. Each 1g sample was homogenized with 10 ml of distilled water [34].

2.2.4 Texture Profile Analysis

A texture analyser (TA.XTplusC Stable Micro System Ltd., Godalming, United Kingdom) was used to determine TPA that consists of parameter firmness of each gluten-free 'banana blossom *keropok lekor*'. The longest side of samples measuring 1x2x5 cm was cut parallel to the principal axis. The sample was compressed, and the biting force was measured in Newtons [35].

2.3 Nutritional Value

2.3.1 Carbohydrate Content

The carbohydrate content of boiled *keropok lekor* samples will be determined using the following Equation [11].

$$\text{Total of carbohydrate (\%)} = 100\% - \% [\text{Moisture Content} + \text{Ash} + \text{Protein} + \text{Fat}] \quad (1)$$

2.3.2 Protein Content

Protein content of the '*banana blossom keropok lekor*' for each formulations sample will be determined using a Kjeldahl apparatus following [12] recommendations. 1 g of the sample will be treated with catalyst before digestion then adding 12 ml of concentrated sulfuric acid and 2 tablets of Cu 3.5 catalyst sulfuric acid (H₂SO₄) to the sample until the mixture turned clear blue or green, indicating complete digestion. After cooling for 10–20 minutes, sodium hydroxide was added to neutralize the sample during distillation. A receiver solution containing 25 ml of 4% boric acid and 10 drops of indicator was prepared, and the mixture was distilled with 70 ml distilled water and 50 ml of 40% NaOH in about 4 minutes. The presence of alkali was confirmed by a green colour change in the receiver solution. The distillate was then titrated with standardized hydrochloric acid (HCl) until it turned pink or red, and the amount of HCl used was recorded to calculate the nitrogen content.

$$\% N = \frac{0.1 \times (A - B) 14.007 \times 100}{\text{weight of sample (g)} \times 1000} \times 100 \quad (2)$$

2.3.3 Fat Content

Soxhlet extraction method, as outlined in [12], was used to determine the crude fat content. 2g of the sample will be placed into a thimble, which will then be inserted into the Soxhlet extraction apparatus and covered with fat-free cotton.

$$\text{Fat (\%)} = \frac{W_3 - W_1}{W_2} \times 100 \quad (3)$$

2.3.4 Energy Content

Energy content will be determined by multiplying the quantities of protein, fat, and carbohydrates by their respective physiological energy values, and then summing up the calculated values as outlined in [12].

$$\text{Energy (kcal)} = (4 \times \text{carbohydrates}) \text{ g} + (4 \times \text{protein}) \text{ g} + (9 \times \text{fat}) \text{ g} \quad (4)$$

2.3.5 Total Sugar

Total sugar content of the sample will be determined following the instructions outlined in [12]. The sucrose solution will be standardized. A mixture of 100 mL of distilled water and 10 g of the '*banana blossom keropok lekor*' sample will be prepared, and the mixture will be neutralized with 1 N NaOH.

2.3.6 Sodium Content

The sodium content will be determined using the Mohr titration method. By titrating the chloride ions with AgNO₃, the sodium ions content of '*banana blossom keropok lekor*' will be determined.

$$\text{NaCl Content (\%)} = \frac{V \times N \times F \times 0.0585 \times 100}{m} \quad (5)$$

2.3.7 Moisture Content

The moisture content of the sample will be determined following the guidelines outlined in [12]. Approximately 5 g of the '*banana blossom keropok lekor*' sample will be transferred and weighed along with its contents. The dish and its contents will be subjected to heating for 3 hours in a 105°C oven. The difference is weight before and after drying will be used to calculate the moisture content, using the following Equation.

$$\text{Moisture (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (6)$$

2.3.8 Ash content

The total ash content of the sample will be determined following the guidelines outlined in [12]. Approximately 5 g of the sample will be carefully placed in a crucible. The crucible containing the sample will then be subjected to heating in a muffle furnace at a temperature of 555 °C for a duration of 5-hours. The final weight of the ashes

sample and crucible will be recorded. The percentage of ash content will then be calculated using the following Equation.

$$\text{Moisture (\%)} = \frac{W_3 - W_2}{W_2} \times 100 \quad (7)$$

3. Result and Discussion

3.1 Physicochemical Analysis

3.1.1 Moisture Content

The moisture content of gluten-free *banana blossom keropok lekor* significantly ($p < 0.05$) differences among the control and gluten-free formulation. The control sample, which used fish as its primary ingredient, showed the highest moisture content (62.31%) compared to the gluten-free formulations. According to research by [12], fish-based products are known for their ability to retain water due to the water-binding properties of fish proteins. Among the gluten-free samples, moisture content differed based on the type of flour used. In Formulation 1 (F1), sweet potato flour (SPF) retained the highest moisture (59.99%), followed by taro flour (TF) at 54.55%, and arrowroot flour (AF) with the lowest moisture content (52.45%). Similarly, in Formulation 2 (F2), sweet potato flour (SPF) (58.73%) showed the highest moisture retention, followed by taro flour (TF) (54.26%) and arrowroot flour (AF) (51.20%). The differences in moisture retention can be attributed to the amylose and amylopectin composition of the flours, as well as their starch granule properties and interaction with other ingredients.

According to [3], arrowroot flour showed the lowest moisture retention, due to its high crystallinity and tightly packed granule structure, which resists water absorption, leading to lower moisture content in the final product. On the other hand, [3] also notes that taro flour, despite having a moderate level of crystallinity, showed the lowest moisture retention among the gluten-free samples. This may be due to its granule integrity at higher temperatures, which limits swelling and water absorption. Sweet potato flour, with its lower crystallinity and more amorphous granule structure, enabled greater water penetration and binding, resulting in higher moisture retention [3]. The differences in amylose and amylopectin content also play a significant role in influencing the moisture retention abilities of these flours. According to [3], arrowroot flour contains 29.39% amylose and 32.87% amylopectin, sweet potato flour has 26.80% amylose and 37.20% amylopectin, while taro flour has the lowest amylose content (17.33%) and the highest amylopectin (48.05%). The higher amylopectin content in sweet potato flour contributes to its greater water-binding ability due to increased swelling and granule breakdown at elevated temperatures. Conversely, taro flour, despite its high amylopectin content, is more crystalline, which restricts swelling and water absorption. Arrowroot flour, classified as a high-amylose flour, showed the lowest moisture content. Its higher crystallinity and firmer gel formation limit water absorption during processing.

Furthermore, according to [13], the influence of freeze-thaw cycles may amplify these moisture differences. Flours with lower crystallinity, such as sweet potato flour, are more susceptible to structural breakdown during freezing and may retain more water after thawing due to damage from ice crystals. This structural breakdown creates more water-binding sites, increasing moisture retention in thawed products. In contrast, flours like arrowroot, with higher crystallinity and compact granule structures, resist such damage, leading to lower absorption and retention in thawed products. Moreover, the change in water absorption or moisture content of *banana blossom keropok lekor* may cause by oyster mushroom and grated coconut addition and/or substitution type of gluten-free flour resulting in the difference of water molecules incorporated in the *banana blossom keropok lekor*.

Table 3 Moisture content of gluten-free banana blossom keropok lekor

Sample/ Formulation	Moisture %	
	Formulation (1)	Formulation (2)
Control	62.31 ± 0.25 ^f	
Arrowroot Flour (AF)	52.45 ± 0.39 ^b	51.20 ± 0.10 ^a
Taro Flour (TF)	54.55 ± 0.36 ^c	54.26 ± 0.15 ^c
Sweet Potato Flour (SPF)	59.99 ± 0.10 ^e	58.73 ± 0.05 ^d

Values are presented as mean ± SD of triplicates. ^{a-f} Mean values with different letters in the same column are significantly different ($p < 0.05$).

3.1.2 Colour

The colour profile of gluten-free *banana blossom keropok lekor* are shown in Table 4. The parameters measured include L* (lightness, where 0 is dark and 100 is white), a* (red-green spectrum, where -100 is green and 100 is red), and b* (yellow-blue spectrum, where -100 is blue and 100 is yellow). The results indicate that different gluten-free flours affect the visual characteristics of gluten-free *banana blossom keropok lekor*.

For lightness (L*) of the sample, the value in AF (F1) sample (49.60) was significantly higher ($p < 0.05$) than other gluten-free sample and the control sample (48.88). The addition of oyster mushroom in formulation 1 significantly increased the whiteness of the gluten-free *banana blossom keropok lekor* sample due to the lower content of myoglobin. According to [14], the concentration of metmyoglobin was decreased in meat products with the present of mushroom extracts. SPF sample in Formulation 1 (F1) had a moderate L* value of 38.57, while taro flour (TF) resulted in the lowest L* value of 28.7, giving it darker appearance. The presence of fish in the control sample may contribute to a slightly darker colour due to the myoglobin and haemoglobin found in fish flesh. Myoglobin is a pigmented protein that gives dark colour to the meat as its percentage is high, which contain pigments that oxidize and deepen the colour [15]. In contrast, banana heart which replaces fish in the experimental samples, contains less myoglobin, resulting in a lighter colour, especially when combined with arrowroot flour.

In terms of redness (a* values), all gluten-free samples were significantly higher ($p < 0.05$) compared to the control sample (2.37). Hence, the value of a* of gluten-free *banana blossom keropok lekor* increased with the addition of oyster mushroom in Formulation 1 since oyster mushroom contains flavonoid as stated by [16], which improved the a* values in samples. The SPF sample in F1 had the highest a* value of 12.23, showing a strong red one. This could be attributed to the presence of oyster mushrooms, which have been shown to contain flavonoids that enhance redness in food products. The control sample, by comparison, had a lower a* value of 2.37, showing a more neutral colour. The arrowroot flour (AF) sample in F2 (a* = 4.27) also had a low redness value similar to the control, suggesting that this flour produces a more neutral effect. The higher a* values observed in SPF formulations are due to the influence of oyster mushrooms, which can increase red hues.

For yellowness (b* values), the SPF samples in F1 (19.24) and F2 (16.63) showed high b* values, resulting in a pronounced yellow tone. Sweet potato flour naturally rich in carotenoids, which intensify yellow hues, and oyster mushrooms may also contribute slightly to this effect. In contrast, the control sample's b* value of 6.36 was significantly lower, suggesting that the fish-based formulation produces a less yellow colour. The TF sample in F2 had a minimal b* value of 0.38, showing almost no yellow, which could be due to taro's lower carotenoid content compared to sweet potato.

Overall, the control sample (Malaysian fish sausage) has a more neutral colour profile, particularly regarding its minimal red and yellow tones. In contrast, sweet potato flour (SPF) adds a vibrant yellow hue to the product, while taro flour (TF) produces a darker, reddish tone, especially in F1. Arrowroot flour (AF) tends to give a lighter appearance, particularly in F1, which enhances the products brightness. This suggests that gluten-free flours, can provide more vivid colour characteristics compared to control sample. Nonetheless, the finished product' colour may be while it is being cooked, impacting the colour of cooked *keropok lekor* [17].

Table 4 Colour properties of gluten-free banana blossom keropok lekor

Sample/ Formulation	Formulation (1)			Formulation (2)		
	L*	a*	b*	L*	a*	b*
Control	48.88 ± 0.77ab			2.37 ± 0.14b		6.36 ± 0.45ab
Arrowroot Flour (AF)	49.60 ± 0.44e	5.26 ± 0.39a	16.2 ± 0.20c	31.70 ± 0.89c	4.27 ± 0.06a	16.07 ± 0.12c
Taro Flour (TF)	28.7 ± 0.66b	9.3 ± 0.36c	7.7 ± 0.10b	16.83 ± 0.74a	6.80 ± 0.86b	0.38 ± 0.73a
Sweet Potato Flour (SPF)	38.57 ± 0.31d	12.23 ± 0.25d	19.24 ± 0.25d	28.43 ± 0.45b	6.53 ± 0.38b	16.63 ± 0.21c

Values are presented as mean ± SD of triplicates. ^{a-c} Mean values with different letters in the same column are significantly different ($p < 0.05$). L*, lightness; a*, redness; b*, yellowness.

pH

The pH variations of gluten-free banana blossom *keropok lekor* observed in Table 4 is influenced by the protein content and flour type used in the formulations, consistent with findings by [36]. From the results, the control sample, which uses fish and wheat flour, has a pH of 6.87. In comparison, *keropok lekor* made with gluten-

free flours shows variations in pH across different flours and formulations. Statistical analysis indicates that sweet potato flour (SPF) and arrowroot flour (AF) formulations have significantly higher pH values than the control ($p < 0.05$), while taro flour (TF) exhibits no significant difference ($p < 0.05$) in either formulation. This suggests that the type of flour and its starch properties play a critical role in influencing the pH of the product. The difference between F1 and F2 could be due to ingredient interactions. F1, which includes acidic components like grated coconut and oyster mushrooms, shows slightly lower pH values, while the absence of these ingredients in F2 allows the pH to rise closer to neutral or slightly alkaline levels.

The control sample, made with fish and wheat flour, maintains a more neutral pH due to wheat flours balanced profile and the protein content from fish, which contributes to a stable, slightly acidic environment. According to [18], the range of pH value of *keropok lekor* were between pH 6.61 to 6.87, making it close to neutral due to the stabilizing effects of fish and wheat flour. The substitution of fish with banana heart, which has a more neutral to alkaline pH, reduces the natural acidity typically introduced by fish proteins.

According to [36] the pH of GF dough is affected by the protein content and acid interactions. In this study, arrowroot flour (AF) formulations exhibited the highest pH (7.23 for F1 and 7.87 for F2), likely due to the high protein content of arrowroot flour (7.7%) [3], which acts as a buffer and stabilizes the pH. Taro flour (TF), with the lowest pH values (6.69 for F1 and 6.73 for F2), reflects its intermediate protein content (5.5%), which contributes to reduced buffering capacity and allows the inherent acidity of other ingredients, such as banana blossom, to dominate. Sweet potato flour (SPF) showed moderate pH values (7.15 for F1 and 7.85 for F2) due to its lower protein content (3.3%), higher natural sugar content, and interactions with acidic ingredients. [36] also noted that the type and concentration of flour influence the pH and behaviour of GF doughs. Differences in starch and amylose content in arrowroot (29.4%), sweet potato (26.8%), and taro (17.3%) [3] likely affected water absorption, swelling, and interactions with proteins, further impacting the pH. For instance, higher amylose content in arrowroot flour may have diluted acidic components during gelatinization, contributing to its higher pH. These results align with [36] findings that pH interactions at the molecular level, particularly between proteins and starch, influence the dough's rheological and structural properties, emphasizing the importance of selecting appropriate flours in GF formulations.

Furthermore, the change in pH observed in gluten-free *banana blossom keropok lekor* after freezing and thawing can attribute the *keropok lekor* to structural and enzymatic changes within a product. During freezing, ice crystals form within the *keropok lekor*, potentially damaging the cellular and starch structures. Additionally, some enzymes may remain active at low temperatures during thawing, and their certain activity can produce certain compounds that influence pH.

Table 5 pH of gluten-free banana blossom keropok lekor

Sample/ Formulation	pH	
	Formulation (1)	Formulation (2)
Control	6.87 ± 0.07 ^a	
Arrowroot Flour (AF)	7.23 ± 0.02 ^b	7.87 ± 0.02 ^c
Taro Flour (TF)	6.69 ± 0.03 ^a	6.73 ± 0.04 ^a
Sweet Potato Flour (SPF)	7.15 ± 0.05 ^b	7.85 ± 0.03 ^c

Values are presented as mean ± SD of triplicates. ^{a-c} Mean values with different letters in the same column are significantly different ($p < 0.05$).

3.1.3 Texture Profile Analysis

The texture profile analysis (TPA) results are presented in table Table 6, detailing firmness for all gluten-free *banana blossom keropok lekor* formulations. The control sample (56.37) significantly ($p < 0.05$) differences compared to gluten-free formulations, reflecting its denser texture. Among the gluten-free formulations in F1, the arrowroot flour (AF) sample (75.87) and sweet potato flour (SPF) sample (74.49) were significantly differences ($p < 0.05$) than taro flour (TF) sample with (32.76). Similarly, for F2, AF (91.45) was the firmest, followed by SPF (60.51), while TF (35.80) exhibited the lowest firmness.

Firmness is a critical parameter for evaluating the texture of food products like *keropok lekor*. As suggested by [20], the textural properties of sausage product are also influenced by the type of different flours used due to the amylose and amylopectin content and structure of each flour, granule size and swelling power of the flours used. Flours with lower swelling power tend to retain less water within the starch matrix, resulting in a firmer texture. This study supports these findings, as the AF based *banana blossom keropok lekor* (AF) exhibited higher firmness, likely due to the relatively low swelling power of AF flour. Flours with lower swelling power retain less water in the starch matrix, forming a harder texture.

A previous study found that fresh Malaysian commercial fish sausages (*keropok lekor*) have a hardness range of 3.3-5.7 kg [21]. The hardness of the samples has been associated with water loss (purge during storage at refrigeration temperatures [22]. Additionally, [23] reported that increasing starch levels can enhance the hardness of fish sausages. The findings from my study indicate that the high level of flour used contributes to the increased firmness of gluten-free *banana blossom kerpok lekor*.

In this study, arrowroot flour (AF) formulations were the hardest due to their lower swelling power, while taro flour (TF), with its higher swelling capacity, produced the softest texture. Sweet potato flour (SPF) showed intermediate hardness due to its balanced starch properties. The findings indicate that the type of flour directly affects the firmness and overall quality of *keropok lekor*, aligning with prior research on starch composition and gel formation. Furthermore, according to [13], arrowroot flour's high amylose content influences its functional and textural properties, making it distinct among gluten-free flours. Products made with arrowroot flour tend to exhibit slightly higher stickiness and hardness due to the strong gel formation attributed to its amylose structure. Overall, the textural profile of gluten-free *banana blossom kerpok lekor* prepared with each gluten-free flour may differ slightly, with sweet potato flour potentially providing a softer texture, taro flour yielding a firmer texture and arrowroot in between.

Table 6 Textural properties of gluten-free banana blossom kerpok lekor

Sample/ Formulation	Firmness (N)	
	Formulation (1)	Formulation (2)
Control	56.37 ± 0.43 ^a	
Arrowroot Flour (AF)	75.87 ± 3.24 ^c	91.45 ± 6.85 ^d
Taro Flour (TF)	32.76 ± 2.04 ^a	35.80 ± 0.91 ^a
Sweet Potato Flour (SPF)	74.49 ± 1.92 ^c	60.51 ± 1.74 ^b

Values are presented as mean ± SD of triplicates. ^{a-d} Mean values with different letters in the same column are significantly different ($p < 0.05$).

3.2 Sensory Evaluation

Based on Table 7, the data presents of the 9-point hedonic test based on the mean score of consumer's preference of gluten-free banana blossom *keropok lekor* formulated with different gluten-free flours which are sweet potato flour (SPF), taro flour (TF), and arrowroot flour (AF) involving 50 panellists. The data are evaluated for six attributes include appearance, taste, colour, aroma, texture, and overall acceptance, where sample AF (F1) was stated as the sample with the highest mean score for appearance, colour, aroma, and overall acceptance. However, the mean score for appearance, colour, aroma, and overall acceptance were significantly differences ($p < 0.05$) for gluten-free containing samples than for control samples.

No significant differences ($p < 0.05$) were observed among the control, SPF and AF samples for appearance for both formulations, with mean scores ranging from 6.46 to 7.28. The control sample, made with fish, scored the highest in appearance likely due to its familiar fish-based composition, with mean score (7.07), significantly higher ($p < 0.05$) than the gluten-free samples except for AF (F1) with the highest mean score (7.28) among gluten-free samples. However, TF samples consistently had the lowest mean scores for both formulations, F1 (4.66) and F2 (4.34), possibly due to the purple coloration that might not align with consumer expectations for *keropok lekor*. This suggests that the different flours did substantially alter the visual appeal of gluten-free banana blossom *keropok lekor*.

In terms of taste, the control sample mean score (7.17) is significantly higher ($p < 0.05$) than the gluten-free banana blossom *keropok lekor* sample. Among the gluten-free samples AF (F1) had the highest taste score (6.76), which was significantly higher than others gluten-free samples. Taro flour consistently received the lowest scores for taste in both F1 and F2. Formulation 1, which includes oyster mushroom and grated coconut, scored higher in taste but scored lower in Formulation 2 which exclude oyster mushroom and grated coconut. Oyster mushrooms are known for their umami-rich flavour, which may have contributed to a savoury depth that differs from traditional fish *keropok lekor*. The grated coconut likely added subtle, natural sweetness that may have appealed to some panellist, although this flavour profile is distinct from the control sample. Studies by [24] suggest that the taste attributes in foods are often linked to their aroma, which may explain the lower scores in taste for gluten-free banana blossom *keropok lekor* versions due to the distinct flavour profile contributed by banana heart.

Regarding colour, the AF sample in Formulation 1 showed a higher preference with mean score (7.30) scored significantly higher ($p < 0.05$) for colour, suggesting the panellists found it more appealing than TF formulations which scored the lowest for colour in both F1 (4.72) and F2 (4.58), significantly lower ($p < 0.05$) than other samples. This is likely due to the distinctive purple hue of taro, which might not be perceived as appealing for *keropok lekor*, indicating that the different flours influence colour acceptability.

For aroma, AF for Formulation 1 with oyster mushroom and grated coconut achieved the highest scored among the gluten-free samples with score mean (6.94) compared to the control sample (6.70), which was not significantly different ($p < 0.05$) from most gluten-free samples except TF for both formulation F1 (5.02) and F2 (5.26), which scored the lowest. The earthy, mildly savoury aroma of oyster mushrooms in F1 may have complemented the arrowroot flour's neutral scent, making it appealing to the panellists. Additionally, the grated coconut may have imparted a light, pleasant fragrance, contributing positively to the aroma. The combination of oyster mushroom and grated coconut in F1 may have enhanced aroma perception, aligning with previous research indicating that mushroom aromas can increase consumer preference for products with distinct, savoury, as seen in studies by [25][26].

In terms of texture, the control sample (6.53) scored significantly higher ($p < 0.05$), than most gluten-free samples and AF (F1) had the highest mean score among the gluten-free samples with (6.36), significantly differences ($p < 0.05$) than arrowroot flour samples which scored lower in F2 (5.04), possibly due to differences in amylose content which may lead to a softer texture that some panellists found less desirable. Additionally, the grated coconut in Formulation 1 may have added slight granularity to the texture, which could influence preference depending on the flour used. However, in Formulation 2, the absence of oyster mushroom and grated coconut may have resulted in a denser texture, which some panellists found less desirable. Arrowroot and sweet potato flour, high in amylose content, might provide a more elastic or chewy texture that some panellists appreciated.

Lastly, the overall acceptance of AF (F1) received the highest mean score (6.90), significantly higher ($p < 0.05$) than the control sample with (6.65). Taro flour formulations had significant differences than other samples ($p < 0.05$) in both formulation F1 (5.52) and F2 (5.12). The favourable acceptance of AF and SPF in Formulation 1 may be due to their texture and flavour characteristics, which align well with traditional fish *keropak lekor* expectations. In comparison, taro flour is scored lower with mean score for both formulations, indicating that the properties of taro flour may require adjustments to improve consumer appeal.

Table 7 Hedonic Test

Attribute	Formulation of Gluten-Free Banana blossom keropak lekor						
	F1				F2		
	Control	SPF	TF	AF	SPF	TF	AF
Appearance	7.07±1.64a	6.54±1.78b	4.66±2.47a	7.28±1.72b	6.06±2.13b	4.34±2.43a	6.46±2.16b
Taste	7.17±1.55a	6.32±1.74bc	5.30±2.17ab	6.76±1.99c	5.66±2.16abc	5.00±2.20a	5.02±2.33a
Colour	5.98±1.67b	6.22±1.77bc	4.72±2.28a	7.30±1.74c	6.06±2.02b	4.58±2.39a	6.78±1.82bc
Aroma	6.70±1.52b	6.64±1.66b	5.02±2.23a	6.94±1.78b	5.98±2.07ab	5.26±2.28a	6.00±2.00ab
Texture	6.53±1.59b	6.40±2.06b	5.86±1.89ab	6.36±2.68b	5.70±2.25ab	5.20±1.96ab	5.04±2.63a
Overall Acceptance	6.65±1.39b	6.60±1.68bc	5.52±2.06ab	6.90±1.76c	5.90±2.01abc	5.12±1.93a	5.44±2.14a

Values are presented as mean ± SD of triplicates. ^{a-c} Mean values with different letters in the same row are significantly different ($p < 0.05$).

3.3 Nutritional Value

The proximate analysis for formulation 1 arrowroot flour is shown in Table 8. The energy content provides the amounts of calories in the product, primarily contributed by carbohydrates, proteins, and fats. The gluten-free *banana blossom keropak lekor* formulated with arrowroot flour in this study, (180 kcal per 100g) demonstrates a significantly lower energy value compared to arrowroot flour alone, which contains 359.66 kcal per 100g, as reported by [27]. This difference is attributed to the incorporation of other ingredients, such as banana heart, oyster mushroom, grated coconut, and tapioca starch, which dilute the overall energy density. While arrowroot flour itself is highly caloric due to its high carbohydrate content, the gluten-free *banana blossom keropak lekor*'s lower energy content highlights the influence of added water content, lower calorie ingredients, and the overall formulation on reducing caloric concentrations. The study suggests that incorporating such diverse ingredients results in a product more suitable for moderate energy consumption while maintaining a balance between nutritional quality and sensory appeal, particularly for gluten-free dietary needs.

The carbohydrate content of the sample was 37.7g. According to [28], tapioca starch contains a high carbohydrate content of 93.12%. Similarly, the carbohydrate content of the *banana blossom keropak lekor* may be influenced by the inclusion of gluten-free arrowroot flour, which has a carbohydrate content of 88.90% [27]. The increase in carbohydrate levels in samples containing oyster mushrooms is attributed to their high carbohydrate content. This aligns with findings by [29], who reported that fresh oyster mushrooms (*Pleurotus ostreatus*) contain approximately 48.16% carbohydrates. The inclusion of grated coconut in the formulation also enhances the carbohydrate content as it contains a high carbohydrate content of 69.99% [30], potentially increasing the overall energy value of the arrowroot gluten-free *banana blossom keropak lekor* which is 180 kcal.

The protein content of the sample was 1.7g. According to the Malaysian Food Regulations 1985, fish keropok should not contain less than 15% protein content. This study proved that substituting the fish with *banana blossom*, could decrease the protein content in *banana blossom keropok lekor*. Another study conducted by [10], discovered that the protein content in the *keropok lekor* was between 8.92-10.80%. This study proves that by substituting fish with *banana blossom in keropok lekor* did effectively decrease the protein content, as fish generally has higher protein content than banana heart.

The high fat content of grated coconut, which contains 25.59% fat, 68.99% carbohydrates, and 0.85% protein [30], explains the elevated fat levels observed in the gluten-free *banana blossom keropok lekor* sample (2.4 g) for formulation 1 with oyster mushroom and grated coconut. While arrowroot flour itself has a low-fat content of 0.26% [27], the addition of grated coconut compensates by providing a substantial amount of fat, contributing to the increased fat content of the formulation.

The total sugar content is relatively low at 1.5%, which indicates that the sweetness of the gluten-free *banana blossom keropok lekor* is minimal. This can be beneficial for consumers looking to reduce their sugar intake while enjoying the product. Natural sugars from ingredients like arrowroot and banana heart may contribute to this value. Sodium often comes from salt, enhances flavour and acts as preservatives. Sodium content at 1000.53 mg is quite high, potentially due to added salt in the formulation, which is typical for snacks but should be monitored for dietary restrictions. High sodium intake can impact blood pressure Malaysian Nutrient Intake (RNI), (2017). According to the [31], the sodium requirement is 1500 mg per day for an average Malaysian adult aged 19 years old and above (MOH, Malaysia, 2017).

Ash content represents the total mineral content in the product. At 1.1%, it shows the presence of essential minerals such as calcium, magnesium, and potassium. These minerals are vital for maintaining health and can enhance the nutritional value of the gluten-free *banana blossom keropok lekor*. The high moisture content of 57% is typical for *keropok lekor*, contributing to its soft and pliable texture. Moisture content indicates water activity, affecting shelf life and texture. Foods with moisture above 50% are classified as perishable and require refrigeration. This necessitates careful storage to prevent microbial growth and spoilage.

Table 8 Proximate analysis of gluten-free arrowroot banana blossom keropok lekor

Parameter	Unit	Value
Energy	kcal/100g	180 kcal (754 kJ)
Total Carbohydrate	g/100g	37.7 g
Protein	g/100g	1.7 g
Total Fat	g/100g	2.4 g
Total Sugar	g/100g	1.5 g
Sodium	mg/100g	1005.3 mg
Ash	g/100g	1.1 g
Moisture	g/100g	57 g

4. Conclusion

The use of gluten-free flours (arrowroot, sweet potato, and taro) as substitute for traditional ingredients in *banana blossom keropok lekor* formulations significantly influenced its physicochemical, sensory, and nutritional properties. Among the gluten-free flours, arrowroot flour exhibited the highest consumer acceptability in terms of taste, aroma, texture, and overall sensory attributes. Arrowroot flour showed good textural stability due to its high amylose content, while taro flour resulted in softer textures and higher moisture content, making it less preferred. Sweet potato flour also performed well in sensory evaluations, offering a softer texture. The inclusion of banana heart as a main ingredient provided a sustainable alternative to fish while enhancing the products nutritional profile with higher fiber content. The nutrient analysis confirmed that the gluten-free *banana blossom keropok lekor* formulations were lower in fat and cholesterol while offering adequate carbohydrates and fiber, making them suitable for health-conscious and gluten-intolerant consumers. The physicochemical properties, including moisture content, pH, and colour, were also significantly affected by the type of flour used. Arrowroot flour, with its high amylose content, resulted in firmer textures, lower moisture content, and good structural stability, particularly during freeze-thaw cycles. Sweet potato flour imparted an appealing golden hue and a slightly higher pH, while taro flour, though nutritionally beneficial, contributed to softer textures, which impacted consumer preference. This study successfully demonstrated the potential of gluten-free flours and banana heart to produce *keropok lekor* with comparable sensory and quality attributes to traditional products, while enhancing its nutritional value.

Acknowledgement

The authors would like to thank the Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Nor Amirah Sahirah Hamdin, Faridah Kormin; **data collection:** Nor Amirah Sahirah Hamdin; **analysis and interpretation of results:** Nor Amirah Sahirah Hamdin, Faridah Kormin; **draft manuscript preparation:** Nor Amirah Sahirah Hamdin, Faridah Kormin. All authors reviewed the results and approved the final version of the manuscript.

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