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Development of Allergen-Free Cookies from Arrowroot and Taro Flours

Nurul Kahirunnisa' Hanis Ramli[1], Aida Safina Aridi[1*]

[1] *Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600, Pagoh, Muar, Johor MALAYSIA*

*Corresponding Author: aidasafina@uthm.edu.my
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Abstract

The increasing prevalence of food allergies and sensitivities, particularly gluten-related disorder has driven demand for safe and nutritious allergen-free alternatives. This study aimed to develop allergen-free cookies using arrowroot and taro flours as substitutes for wheat flour, evaluating their physicochemical properties and sensory acceptability to determine the most preferred cookies. Allergen-free cookies made from arrowroot flour had a softer texture with hardness of 149.23 ± 25.26N and fracturability of 9.42 ± 1.00 mm, while cookies from taro flour exhibits firmer texture with hardness of 267.22 ± 12.31 N and fracturability of 8.97 ± 0.69 mm. In colour analysis, both exhibiting lighter colours with reddish and yellowish hues. Moisture content for both samples was low in the range of 6%, ensuring extended shelf life by minimizing microbial growth. Unexpectedly, the ash content was higher in cookies from arrowroot flour (1.43 ± 0.33%) than those with taro flour (0.44 ± 0.19), possibly due to errors in combustion time during ash analysis. Protein analysis showed higher protein content in cookies made from taro flour (3.24 ± 0.01%) compared to those with arrowroot flour (1.24 ± 0.03%) though the difference was not statistically significant. Sensory evaluation using a 9-point hedonic scale revealed cookies from arrowroot flour achieved a higher overall acceptability score (6.51 ± 1.690) compared to cookies from taro flour (5.86 ± 1.662). The study concluded that allergen-free cookies from arrowroot flour were the most favoured by panellists, offering desirable sensory attributes and potential nutritional benefits. The study contributes to the development of allergen-free products, catering to the growing consumer demand for safer and high nutritional value alternatives. Future research could explore ingredient modifications to further enhance texture and improve storage stability to optimize the formulation for commercial production.

1. Introduction

Food allergies and gluten-related disorders, such as celiac disease, wheat allergy and non-celiac gluten sensitivity, cause a significant dietary challenge for affected individuals. These conditions force a strict diet towards ingredients containing gluten and allergens, which are commonly found in staple food. Major food allergens include milk, eggs, fish, shellfish, tree nuts, peanuts, wheat and soybeans.

The prevalence of gluten-related disorders has been increasing globally, affecting 8.4% of the world population as reported in 2020 [1]. 6% of the world population suffered from non-celiac gluten sensitivity with the remaining 1.4% and 1% faced celiac disease and wheat allergy respectively [2]. In Malaysia, the rising demand for gluten-free products has driven significant sales growth, increasing from USD 5.14 billion in 2016 to USD 21.61 billion in 2019. This trend is expected to continue, with a projected compound annual growth rate (CAGR) of 9.2% from 2020 to 2027 [3]. Moreover, the challenge of maintaining desirable sensory and nutritional qualities in gluten-free baked goods often results in products that are less appealing than their gluten-containing counterparts [4].

In response to the growing demand for safe and nutritious alternatives, this study focuses on developing allergen-free cookies using arrowroot and taro flours as the substitutes for wheat flour. Both flours are reported to be hypoallergenic, as they are naturally gluten-free and allergen-free. Additionally, gluten-free products exclude gluten which is a protein found in wheat, barley and rye [5]. In contrast, allergen-free products cater those individuals with multiple food allergies, eliminating common allergens such as wheat, dairy, eggs, milk ad soy.

Arrowroot (*Maranta arundinacea*) and taro (*Colocasia esculenta*) flours present promising solutions for developing allergen-free cookies. Both flours have hypoallergenic properties, meaning they are both gluten-free and allergen-free, making them essential for producing food products suitable for individuals with multiple food allergies. Arrowroot flour is known for its easy digestibility and low glycaemic index, making it ideal for individuals with digestive issues and dietary restrictions [6]. Additionally, it contains carbohydrate, protein, fiber and good source of minerals which are important in producing nutritious food product [7].

Taro flour widely known as a functional and nutritional ingredient, offering rich source of carbohydrate, high dietary fiber and mineral, such as potassium and calcium. It often used in producing baby foods, as it is high digestibility and resistant starch content, enhancing their digestive system. Its hypoallergenic nature makes it appealing in producing products that cater individuals with dietary restrictions such as gluten-related disorders [8].

Previous studies have reported that gluten-free products tend to have low nutritional content and poor texture profile due to absence of gluten [9]. Thus, this study utilizes highly nutritious and hypoallergenic flours, arrowroot and taro flours in order to develop both nutritious and safe allergen-free cookies. The aim of this study is to investigate the effect of arrowroot flour and taro flour on the physicochemical properties of the cookies, as well as to identify the most preferred cookies through sensory evaluation test. Sensory evaluation helps assess the acceptability and preference of consumers based on appearance, aroma, texture, taste and overall acceptability. It also aids in comparing different types of flour used and provide valuable insights into consumer preference for product development.

Cookies are chosen for this study as they are convenience and enjoyed by all generations. Cookies are a widely popular snack enjoyed across all age groups, valued for their variety, flavour and convenience [10]. However, individuals with food allergies, particularly gluten-related disorders such as celiac disease, wheat allergy and non-celiac gluten sensitivity, face significant dietary restrictions that limit their ability to consume conventional cookies. Thus, these conditions involve the elimination of wheat and other gluten-containing ingredients, creating a need for safe and appealing gluten-free alternatives.

2. Material and Methods

2.1 Samples Preparation

Cookie samples were prepared in the Bakery, Snack and Confectionery Technology Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM). The main ingredients consist of flour, honey, sunflower seed oil and other ingredients in a small quantity such as vanilla essence, salt and soda bicarbonate. The alternative flour used in this cookie formulation is arrowroot and taro flours in substituting wheat flour. The complete ingredients of cookie formulation are displayed in Table 1.

Table 1 The Quantity of Each Ingredient Used in Cookie's Formulation

Ingredients	Quantity (gram)
Flour*	50
Honey	42
Sunflower seed oil	14
Vanilla essence	3
Salt	0.1
Soda bicarbonate	0.1

*The flour was substitute with arrowroot and taro in the same quantity

The quantity of ingredients was identified through several trials' session for each flour, multiple formulations were tested to achieve the desired cookie texture, taste and structure. Various temperature and baking time combinations were experimented with to optimize the baking conditions. Initial trials involved baking at different temperature ranges (e.g., 150°C - 180°C) and varying baking duration (e.g., 9-15 minutes) to evaluate their effects on cookie spread, texture and overall quality. Adjustments were made to ingredient proportions, such as flour-to-oil-to-honey ratio to ensure proper dough consistency. For instance, 2.5:1:1, 3:1:1, 4.5:1:2 and 25:7:21.

The cookie making process was inspired by [12] and begins with prepared the ingredients in the stated amount. The dry ingredients such as flour, salt and soda bicarbonate were mixed well using a spatula. Then, wet ingredients such as honey, sunflower seed oil and vanilla essence were added to the well mixed dry ingredients. Continue mixing the ingredients until well mixed. Next, the dough was moulded into a small ball and placed on a baking tray layered with baking paper. The dough was baked in a pre-heat oven at 160°C for 11 minutes. Then, the cookie samples were cut into small pieces with approximately 1cm x 1cm after cooling down for a few minutes. The small pieces of sample were placed in a small baking paper cup coded with a three-digit random number. The flow diagram of the processing steps is displayed in Fig. 1.

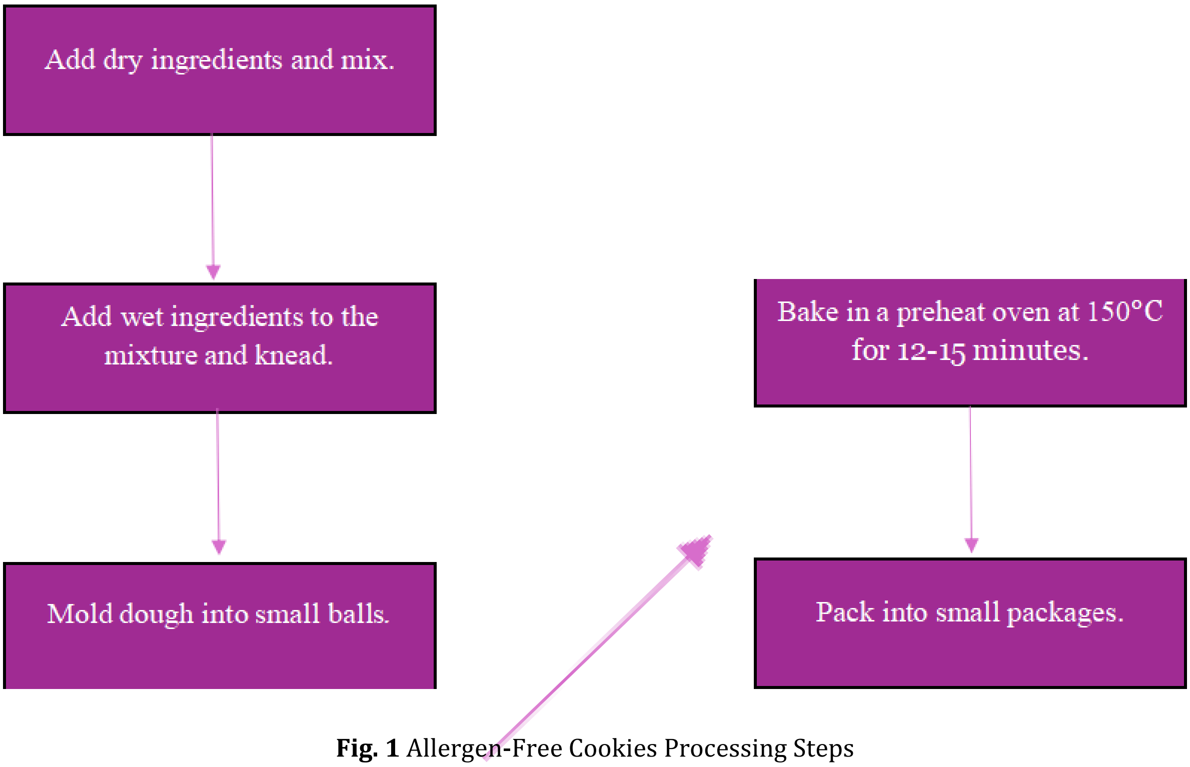

Fig. 1 Allergen-Free Cookies Processing Steps

Fig. 2 The Visual of The Cookies After Baking

2.2 Respondents

The respondents participated in the sensory evaluation of allergen-free cookies made from arrowroot and taro flours were 51 individuals. 66.7% female and 33.3% male were contributed to this sensory evaluation with range age of 18-32 years old. Among the respondents, 45% (23 individuals) reported having dietary restrictions. Specifically, 13.7% followed a strict vegan diet, while 17.6%, 3.9%, 5.9% and 3.9% adhered to gluten-free, dairy-free, egg-free and nut- free diets respectively.

The sensory evaluation forms were given in a digital form and a consent form were distributed to the respondents by using Google Form. Consent form informed the participants about the study's purpose and their rights before participation. The involvement of the respondent was voluntary and individuals had the right to withdraw at any time during the session.

2.3 Sensory Evaluation

A sensory evaluation was carried out at the Food Sensory Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM). 51 untrained panellists were invited to evaluate the allergen-free cookies which involve 2 types of samples, cookies made using arrowroot flour and taro flour. A cup of water was provided to the panellists to rinse their mouth before and between evaluating each sample.

A 9-point hedonic scale, ranging from extremely dislike to extremely like, was employed to thoroughly evaluate the sensory attributes of the allergen-free cookies. This scale allows for a detailed assessment of taste, texture, aroma, appearance and overall acceptability to investigate in depth consumer preferences [11]. Then, the collected data was analysed using ANOVA test to conclude the consumer preferences.

2.4 Texture Analysis

The texture of the final allergen-free cookie was tested by using texture analyser. The model of texture analyser used was a Texture Analyzer Stable Micro Systems TA.XTPlusC at Food Instrumental Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM). The analysis was to determine the hardness and fracturability of the cookies by using three-point bend rig probe with a distance being 5.00 mm between the cookies on a hard surface. The pre-test, test and post-test speed were 1.00 mm/sec, 3.00 mm/sec and 10.00 mm/sec respectively. The texture analysis was done in triplicate.

2.5 Colour Analysis

Colourimeter of model STP SPL 3000 was used in analysing the colour attributes of the allergen-free cookies. A beam of light emitted though a sample and then measuring how the sample changes the light. The light first goes through a filter to isolate specific colours, then reaches a detector measures the intensity of the light. L*a*b* acts as a colour coordinator in expressing the colour attributes. These attributes consist of L* (ranging from L* = 0 for black to L* = 100 for white), a* (with -a* indicating greenness and +a* indicating redness) and b* (with -b* signifying blueness and +b* signifying yellowness), collectively serving as numerical indicators for determining colour attributes [12]. Before conducting L*a*b* measurements, the colourimeter must be calibrated by allowing the device to warm up before inserting a cuvette with distilled water, close the lid and press the calibration button. Wait for the light to turn off, then remove and reinsert the cuvette. Finally, start the measurement and ensure all colour readings are near 100% transmittance.

2.6 Moisture Analysis

The moisture content of the allergen-free cookie sample was determined using a digital moisture analyser, the A&D MX-50 model. Approximately 5 grams of cookie sample were placed evenly on the aluminium pan of the moisture analyser in order to ensure uniform drying. The device was set to heat the sample at 140 ∘ C as stated in the user manual with an estimated time of 5.5 minutes. The drying process continued until a constant percentage shown on the screen display indicated the drying process was done. The percentage of moisture was calculated based on the initial weight and the weight loss during the drying process, resulting in a measure of water content in the cookie sample [8]. The analysis was performed in triplicate to ensure precision, with the average moisture percentage calculated to provide a more accurate result.

2.7 Ash Analysis

Ash content was analysed using muffle furnace method to determine the total inorganic residue left in the cookie [13]. A clean crucible was pre-heated in a muffle furnace at 550 ∘ C for 30 minutes before weighed up to obtain the initial weight. Approximately 3 grams of each finely ground sample were placed in the crucible and burned on the Bunsen burner before heated in a muffle furnace. The heating continued until the residue turned greyish white, indicating complete combustion of organic materials. The crucible was then cooled in a desiccator to prevent any moisture absorption before weighing. Ash content was calculated as the percentage of the remaining residue relative to the initial sample weight.

The ash content can be calculated using the following formula:

$$Ash\ Content\ (\%) = \left(\frac{W3 - W1}{W2 - W1}\right) \times 100 \quad (1)$$

Where:
W1 = Weight of the empty crucible
W2 = Weight of the crucible with the sample before ashing
W3 = Weight of the crucible with the ash after ashing

2.8 Protein Analysis

The protein content of the allergen-free cookies was analysed using the Kjeldahl method, a widely used technique for analysing nitrogen content in food samples [13]. The samples were digested in concentrated sulfuric acid with a catalyst to convert all nitrogen into ammonium sulphate. The digested sample was then distilled, with ammonia released into a receiving solution of boric acid. The ammonia was titrated with a standardized hydrochloric acid to determine the amount of nitrogen present. Then, the total protein content was calculated using a conversion factor of 6.25.

2.9 Statistical Analysis

Statistical analysis was conducted using IBM SPSS Statistics Version 26. An independent samples t-test was applied to compare the texture profile, colour profile, moisture content, ash content and protein content between the allergen-free cookies. Results were presented as mean ± standard deviation, with statistical significance set at $p<0.05$.

3. Results and Discussion

3.1 Sensory Evaluation of Allergen-Free Cookies

Sensory attributes of the allergen-free cookies had been evaluated by the panellists, the sensory attributes assessed by the panellists include appearance, aroma, texture, taste and overall acceptability using 9-point hedonic scale. Two samples were distributed to the panellist which were made from two different types of flour, arrowroot and taro flours. Then, the collected data was analysed and interpreted by using One-way ANOVA through IBM SPSS Statistics Version 26. ANOVA or Analysis of Variance was conducted to compare the sensory attributes of allergen-free cookies made from arrowroot and taro flours, determining whether significant differences existed among these attributes.

Table 2 Descriptive Table

	Sample	Mean
Appearance	Arrowroot flour	6.10 ± 1.616a
	Taro flour	6.78 ± 1.747b
Aroma	Arrowroot flour	6.96 ± 1.843a
	Taro flour	6.31 ± 1.794a
Texture	Arrowroot flour	5.80 ± 1.822b
	Taro flour	4.94 ± 1.974a
Taste	Arrowroot flour	6.57 ± 1.781a
	Taro flour	6.33 ±1.956a
Overall acceptability	Arrowroot flour	6.51 ± 1.690a
	Taro flour	5.86 ± 1.662a

* Different letters indicate significant differences at p<0.05.

Table 2 presents the descriptive statistics summarizing the sensory evaluation results for allergen-free cookies made from arrowroot and taro flours. The table includes key sensory attributes such as appearance, aroma, texture, taste and overall acceptability, with mean scores and standard deviations recorded for each attribute. The mean score represents the average rating given by panellists on a 9-point hedonic scale while standard deviation indicated the variation in responses among panellists.

Table 3 Test of Homogeneity of Variances

	Levene statistic	Df1	Df2	Significance value
Appearance	0.412	1	100	0.522
Aroma	0.029	1	100	0.864
Texture	0.264	1	100	0.608
Taste	0.039	1	100	0.844
Overall acceptability	0.059	1	100	0.808

* Different letters indicate significant differences at p>0.05.

Table 3 shows the Test of Homogeneity of Variances for each sensory attribute of allergen-free cookies from arrowroot and taro flours. This test determines whether the variances of the two samples are statistically equal, ensuring the validity of further statistical analysis. The results indicate that the significance values for all sensory attributes are greater than 0.05 ($p>0.05$). This suggests that the assumption of equal variances is met, meaning there are no significant differences in variance between the two cookie samples. Thereby, the significance value from ANOVA analysis in Table 4 was used for further statistical interpretation.

The ANOVA analysis results for appearance and texture showed significance values less than 0.05 ($p<0.05$). This indicates that there is a statistically significant difference between the cookies made from arrowroot and taro flours in terms of these attributes. Panellists perceived a notable difference in appearance might be due to the visual between the two cookie samples. The texture was also significantly different, likely due to the notable hardness between the cookies made from arrowroot flour and cookies made from taro flour.

Statistical analysis revealed a significant difference in appearance ($p=0.042$) and texture ($p=0.024$) between cookies made from arrowroot and taro flours. As for the appearance of the allergen-free cookies, cookies made from arrowroot flour has a mean score of 6.10 ± 1.616 while taro flour is 6.78 ± 1.747. Based on [5], it showed that the cookies made from arrowroot flour is 6.24 ± 0.06. Meanwhile based on [12], cookies made with taro flour is 7.26 ± 1.68. Both of the studies have a slightly different with the data obtained. Thus, this proves that the appearance of the cookie made from taro flour is more favoured than arrowroot flour. This is likely because cookies made from taro flour appear puffier than those made with arrowroot flour. A previous study reported no significant difference in appearance between cookies made with taro flour and wheat flour cookies, indicating that taro flour can produce a visual similar to traditional wheat-based cookies [12].

Despite of that, the texture of allergen-free cookies made from arrowroot flour (5.80 ± 1.822) is considered more favoured as it has higher mean than taro flour (4.94 ± 1.974). The data from the same studies concluded that the cookies made with arrowroot flour (7.38 ± 0.08) is higher than those of taro flour (7.33 ± 1.78). This could be attributed to the fine starch granules of arrowroot flour, which create an airy and soft texture as well as its gelatinization and binding properties may have contributed to a more cohesive structure, making it the preferred option among panellists [14].

Table 4 ANOVA Analysis

		Sum of squares	Mean square	Significance value
Appearance	Between groups	12010	12.010	0.042
	Within groups	283.137	2.831	
Aroma	Between groups	10.676	10.676	0.075
	Within groups	330.902	3.309	
Texture	Between groups	18.980	18.980	0.024
	Within groups	360.863	3.609	
Taste	Between groups	1.412	1.412	0.527
	Within groups	349.843	3.498	
Overall acceptability	Between groups	10.676	10.676	0.054
	Within groups	280.784	2.808	

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The significance value for overall acceptability presents in the Table 4 shows no statistically significant difference between cookies made from arrowroot flour and taro flour. The *p*>0.05 indicates that panellists rated both cookie samples similarly. However, mean of overall acceptability for the two cookie samples were compared, revealed that cookies made from arrowroot flour (6.51 ± 1.690) has a slightly higher mean than those made from taro flour (5.86 ± 1.662). According to the same studies, cookies from arrowroot flour (7.56 ± 0.34) has the higher overall acceptance than those with taro flour (7.38 ± 1.60).

This means that although there was no significant difference between the two cookie samples, arrowroot flour cookies were slightly more preferred by the panellists. This is likely attributed to the pleasant honey aroma, soft and airy texture as well as well-balanced sweet taste. According to previous study, taste of the cookies is the leading factor influencing consumer preferences, as it creates emotional connections through familiar flavours. Additionally, flavour variety and sensory appeal play a crucial role in attracting consumer attentions, making taste a key driver of product acceptance and satisfaction [15].

3.2 Texture Analysis

Table 5 Texture and Colour Analysis for Each Cookie Sample

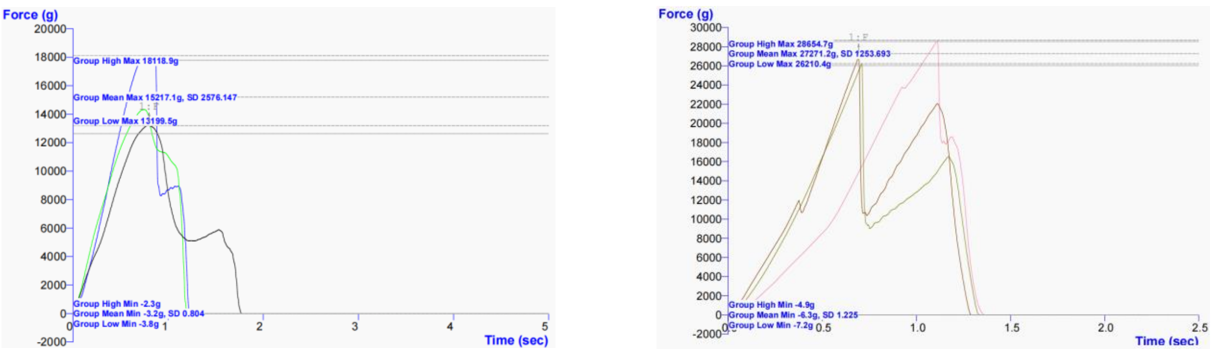
Samples	Texture analysis		Colour		
	Hardness (N)	Fracturability (mm)	L*	a*	b*
Arrowroot flour	149.23 ± 25.26a	9.42 ± 1.00a	73.08 ± 1.07a	2.97 ± 0.08a	11.78 ± 0.41a
Taro flour	267.44 ± 12.31a	8.97 ± 0.69a	65.03 ± 3.16a	1.18 ± 0.08a	9.55 ± 0.78a

* Different letters indicate significant differences at p>0.05.

Results shown in Table 5 are the data recorded for the texture and colour analysis of allergen-free cookies made from arrowroot and taro flours. The independent samples t-test was conducted to identify whether the data collected is statistically significant difference or not, resulting in both of the texture attributes have significance values greater than 0.05 (*p*>0.05). This indicates no statistically significant differences of the attributes between the cookie samples.

Generally, hardness in texture analysis refers to the maximum force required to break or deform the sample. Higher hardness value indicates a firmer texture meanwhile lower hardness value displays a softer texture. On the other hand, fracturability represents brittleness by identifying the distance at which the sample breaks under applied force. A higher fracturability values indicate a longer breaking distance, suggesting greater flexibility before breaking. Conversely, a lower fracturability value with shorter breaking distance means the cookie is more brittle.

Arrowroot flour known for its high amylose content, absorbs more water and forms a gel-like structure, contributing to a softer cookie [13]. Meanwhile, the starchy nature of taro flour contributes to a cohesive texture by retaining moisture, preventing the cookies from becoming too dry and overly crumbly [8]. Since there is no statistically significant difference in the texture of both cookie samples, the result suggests that both of the cookies from arrowroot and taro flours have the same texture profile, where cookies from arrowroot flour have soft texture while cookies from taro flour have cohesive texture. A previous study found that cookies with a crunchy texture received a significantly higher liking scores, as enhanced mouthfeel and crispness contributed to a more appealing texture profile [12].



(a) Cookies from arrowroot flour (b) Cookies from taro flour

Fig. 3 Texture Profile of Each Cookie Samples

3.3 Colour Analysis

Regarding colour analysis, a colourimeter was used to assess the colour of the allergen-free cookies and provided the values in the L*a*b* colour space. The results from the table indicate that there is no statistically significant difference in colour between the cookies from arrowroot and taro flours. L* represents brightness, ranging from 0 (black) to 100 (white). For instance, higher values indicate lighter colour while lower values indicate darker colour [12]. Based on Table 5, it shown that both of the cookie samples have lighter colour as they have high value of L*. Consumer associate lighter colours may indicate underbaking while darker colours may signal overbaking or caramelization while slightly golden-brown often associate with a well-baked cookie.

Meanwhile, the a* values represent the red-green axis, where positive values indicate redness and negative values indicate greenness. Both allergen-free cookies made from arrowroot flour (2.97 ± 0.08) and taro flour (1.18 ± 0.08) exhibit positive values, proving a reddish tone. This redness associated to the browning reactions such as Maillard reactions occur during the baking process and contribute to the visual colour [16].

The b* values of the allergen-free cookies, representing yellow-blue axis. Positive values indicate yellowness and negative values indicate blueness. The cookie made with arrowroot flour has a b* value of 11.78 ± 0.41 meanwhile taro flour is 9.55 ± 0.78, both indicating the yellowish colour. This indicates the natural pigments of the flours, meanwhile a slightly yellow hues in cookies are perceives as rich and slightly sweeter.

(a) Cookies from arrowroot flour

(b) Cookies from taro flour

Fig. 4 Colour Profile of Each Cookie Samples

3.4 Moisture Analysis

Table 6 Data of Moisture Content, Ash Content and Protein Content of Each Cookie Sample

Samples	Moisture content (%)	Ash content (%)	Protein content (%)
Arrowroot flour	6.81 ± 0.03[a]	1.43 ± 0.33[a]	1.24 ± 0.03[a]
Taro flour	6.61 ± 0.69[a]	0.44 ± 0.19[a]	3.24 ± 0.01[a]

* Different letters indicate significant differences at p>0.05.

An A&D MX-50 model of moisture analyser was used to determine the moisture content of the allergen-free cookies. The moisture content is typically expressed as a percentage of the product's weight. High moisture content indicates more water in the product, which can affect the texture, microbial stability and spoilage risk. Meanwhile, low moisture content illustrates a drier product, which is often desirable for extended shelf life in goods like cookies [8].

(a) Cookies from arrowroot flour

(b) Cookies from taro flour

Fig. 5 Moisture Analysis of Each Cookie Samples

According to Table 6, both of the cookie samples have a moisture content in the range of 6%, which is considered as a low moisture content. According to [5], the moisture content of cookies from arrowroot flour is 8.92 ± 0.33% while previous study by [12] is 4.16 ± 0.11%. Both studies shows that cookies made from arrowroot and taro flours have a low moisture. Low moisture content helps achieve a crunchy texture as well as extends shelf life by inhibiting microbial growth [8]. Most bacteria require water activity (a_w)>0.60 to grow, making 6% moisture content sufficiently low to inhibit microbial growth and prevent spoilage. As a result, cookies with low moisture levels have an extended shelf life and remain for consumption. Additionally, an increase in moisture content leads to a decrease in hardness, resulting in a softer and soggy texture. In contrast, low moisture cookies retain their crispness and crunchiness, making them less prone to spoilage while maintaining their desirable texture, resulting in high consumer acceptability [17].

3.5 Ash Analysis

The ash content of allergen-free cookies was analysed through a combustion process using muffle furnace. The aim of ash analysis was to measure the inorganic mineral residue left after the combustion of organic matter in a sample. It also reflects the total mineral content of the product, which can indicate nutritional value or ingredient composition [13]. Higher ash content indicates a greater concentration of minerals meanwhile lower ash content indicates a lower mineral contribution.

(a) Cookies from arrowroot flour (b) Cookies from taro flour

Fig. 6 Ash Analysis of Each Cookie Samples

As shown in the table, there is no statistically significant difference (p>0.05) in ash content between allergen-free cookies from arrowroot flour (1.43 ± 0.33 %) and those made from taro flour (0.44 ± 0.19 %). Taro flour is typically rich in minerals such as calcium, potassium and magnesium as reported by [12] shows ash content of 1.95 ± 0.09 %. Meanwhile based on previous study by [18], cookies made with arrowroot flour has ash content of 0.94 ± 0.34 %. Based on these studies, it proves that cookies made from taro flour has high mineral than those made with arrowroot flour. Cookies with high mineral content may appeal to health-conscious consumers, particularly those in urban areas, where there is a high demand for nutrient-rich foods. In contrast, consumers in rural areas often prefer traditional products align with their local dietary habits and cultural preferences.

These minerals contribute significantly to the ash content; therefore, cookies made with taro flour would be expected to have a higher ash content than those made with arrowroot flour, which is naturally low in minerals. Data error could be due to the combustion time during ash analysis that might yield inaccurate results. If the combustion time was too short, some organic material may not have fully incinerated, resulting in lower ash content than expected. Conversely, if the sample was overheated for too long, certain minerals may have volatilized, leading to lower measured ash content.

3.6 Protein Analysis

For the protein analysis of allergen-free cookies, Kjeldahl method was performed to determine the protein content [13]. Protein content indicates the proportion of protein in a product, typically expressed as a percentage. Based on the result, the percentage of protein content in cookies made with arrowroot flour is 1.24 ± 0.03 % and those with taro flour is 3.24 ± 0.01 %. However, statistical analysis showed no significant difference (p>0.05) in protein content between cookies made from arrowroot and taro flours. The slightly numerical difference of protein content in the cookies from taro flour reflects the naturally higher protein levels in taro flour compared to arrowroot flour. Study by [19] concluded that the protein content of cookies made from taro flour is 2.4% while study by [20] showed the protein content of cookies made from arrowroot flour (0.72%), proving that the cookies made from taro flour has higher protein content than those made with arrowroot flour. According previous study, 30% of individuals in Malaysia prefers the nutritional aspects of cookies, emphasizing features like low sugar content, gluten-free formulations and high protein options to support their dietary preferences [15].

4. Conclusion

This project focused on developing allergen-free cookies using arrowroot and taro flours as alternatives to wheat flour. The objectives included evaluating physicochemical properties and sensory attributes of the cookies to determine the most preferred formulation. Although statistical analysis showed no significant difference between the cookie samples, allergen-free cookies from arrowroot flour were the most preferred formulation, as indicated by higher mean scores. Cookies from taro flour received higher mean scores in appearance despite there is no statistically significant difference showed, due to its puffier visual similar to wheat-based cookies. In contrast, cookies from arrowroot flour have higher means in texture, attributed to the soft and airy texture. Results showed that cookies from arrowroot flour were softer and more flexible, with lower hardness (149.23 ± 25.26 N) and higher fracturability (9.42 ± 1.00 mm), while cookies from taro flour were firmer and more brittle, with higher hardness (267.22 ± 12.31 N) and lower fracturability (8.97 ± 0.69 mm). Colour analysis revealed that cookies from arrowroot flour were lighter (L*=73.08 ± 1.07) and more yellow (b*=11.78 ± 0.41), while cookies from taro flour showed a redder tone (a*=1.18 ± 0.08) due to the Maillard reaction. Both cookies had low moisture content which is in the range of 6%, ensuring extended shelf life. Unexpectedly, cookies from arrowroot flour have a higher ash content (1.43 ± 0.33%) than cookies from taro flour (0.44 ± 0.19%), due to error in combustion time during ash analysis. This issue could be further investigated in future studies. While cookies from taro flour exhibited higher protein content (3.24 ± 0.01%) compared to those from arrowroot flour (1.24 ± 0.03%), these differences were not statistically significant. Protein in both flours is essential as it aids in muscle growth, weight management, blood sugar regulation, easy to digest, gluten free, making it ideal for individuals with celiac disease [5]. Thus, key attributes such as hypoallergenic properties, high nutritional value and easy digestibility of both flours, making allergen-free cookies a viable commercial product for health-conscious, gluten-related disorders and digestive issue individuals. For future research, further improvement could be made by modifying ingredients to enhance texture, improving storage stability on the allergen-free cookies to provide safe and nutritious choices for wider target consumer.

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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:*** *Nurul Kahirunnisa' Hanis Ramli;* ***data collection:*** *Nurul Kahirunnisa' Hanis Ramli;* ***analysis and interpretation of results:*** *Nurul Kahirunnisa' Hanis Ramli, Aida Safina Aridi;* ***draft manuscript preparation:*** *Nurul Kahirunnisa' Hanis Ramli, Aida Safina Aridi. All authors reviewed the results and approved the final version of the manuscript.*

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