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Research Paper / Araştırma Makalesi

Quality Characteristics of Cookies Made with Red Rice Flour Composite Flour

Leong Kar Yee[1], Syaidahtull Naseha Ibrahim[1], MacDalyna Esther Ronie[1], Ahmad Hazim Abdul Aziz[1], Rovina Kobun[1], Wolyna Pindi[1], Jumardi Roslan[1], Norazlina Md Ridhwan[1], Nicky Rahmana Putra[2], Hasmadi Mamat[1] ✉

[1]Faculty of Food Science and Nutrition, University Malaysia Sabah, 88400 Kota Kinabalu Sabah, Malaysia
[2]Research Center for Pharmaceutical Ingredients and Traditional Medicine, National Research and Innovation Agency, Bogor 16911, Indonesia

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✉ *Corresponding author (Yazışmalardan Sorumlu Yazar): idamsah@ums.edu.my (H. Mamat)*
✆ +60162629496 🖷 +60088320259

ABSTRACT

Red rice flour (RRF) is renowned for its nutritional richness, particularly in terms of total dietary fiber and essential minerals. This flour is derived from red rice, a variety of rice known for its distinctive red husk and bran layer. The study aimed to identify the best formulation through sensory evaluation, determine nutritional composition, physical characteristics, and assess shelf life compared to a control cookie. Five formulations of red rice cookies were prepared with RRF substitution levels ranging from 20% to 100%. The F2 red rice cookie with 40% RRF substitution was chosen as the best formulation based on sensory evaluation. It showed similarities to the control cookie in terms of sensory attributes. Nutritional analysis revealed lower moisture and crude protein content but higher crude fiber and total dietary fiber in the F2 compared to the control. Physical analysis showed lower hardness and different color characteristics for the F2. Consumer study results indicated high acceptability for the F2 red rice cookie. In conclusion, this study offers a promising strategy to improve the nutritional profile of cookies by boosting their dietary fiber content, effectively addressing a common deficiency observed in cookies made with conventional wheat flour

Keywords: Cookies, Pigmented rice, Rice flour, Sensory evaluation, Proximate composition

Kırmızı Pirinç Unu Karışımıyla Yapılan Kurabiyelerin Kalite Özellikleri

ÖZ

Kırmızı pirinç unu (KPU), özellikle toplam diyet lifi ve temel mineraller açısından besin zenginliği ile tanınır. Bu un, kendine özgü kırmızı kabuk ve kepek tabakasıyla bilinen bir pirinç çeşidi olan kırmızı pirinçten elde edilir. Çalışma, duyusal değerlendirme yoluyla en iyi formülasyonu belirlemeyi, besin bileşimini, fiziksel özellikleri incelemeyi ve kontrol kurabiyesine kıyasla raf ömrünü değerlendirmeyi amaçlamıştır. Kırmızı pirinç kurabiyelerinin beş farklı formülasyonu, %20 ile %100 arasında değişen KPU ikame seviyeleriyle hazırlanmıştır. Duyusal değerlendirme sonuçlarına göre, %40 KPU ikamesi ile hazırlanan F2 kırmızı pirinç kurabiyesi en iyi formülasyon olarak seçilmiştir. Duyusal özellikler açısından kontrol kurabiyesine benzerlik göstermiştir. Besin değeri analizi, F2'nin kontrol kurabiyesine kıyasla daha düşük nem ve ham protein içeriğine, ancak daha yüksek ham lif ve toplam diyet lifi içeriğine sahip olduğunu ortaya koymuştur. Fiziksel analiz, F2'nin daha düşük sertlik ve farklı renk özelliklerine sahip olduğunu göstermiştir. Tüketici çalışması sonuçları, F2 kırmızı pirinç kurabiyesinin yüksek kabul gördüğünü göstermiştir. Sonuç olarak, bu çalışma, geleneksel buğday unu ile yapılan kurabiyelerde yaygın olarak görülen diyet lifi eksikliğini etkili bir şekilde ele alarak, kurabiyelerin besin profilini iyileştirmek için umut verici bir strateji sunmaktadır.

Anahtar Kelimeler: Kurabiye, Pigmentli pirinç, Pirinç unu, Duyusal değerlendirme, Yaklaşık bileşim

INTRODUCTION

Cookies are a popular convenience snack favored by individuals with busy lifestyles due to their grab-and-go nature and extended shelf life compared to other baked goods [1, 2]. Cookies provide significant amounts of nutrients such as minerals, protein, fiber, and some vitamins, contributing to our dietary intake and meeting daily nutritional needs [3, 4]. However, traditional cookies, primarily composed of wheat flour, eggs, sugar, and butter, are often considered unhealthy due to their high starch content, low dietary fiber, and gluten intolerance issues [5, 6].

In efforts to develop healthier cookies with enhanced nutritional and textural attributes, various studies have explored the substitution of wheat flour with different rice flour, offering gluten-free options with added nutritional benefits [7-10]. Bolarinwa et al. [5] demonstrated that a blend formulation of germinated brown rice flour and potato starch yielded quality gluten-free cookies. Similarly, Klunklin and Savage [11] investigated the effects of substituting purple rice flour for wheat flour in biscuits, resulting in improved nutritional properties and reduced starch digestibility. Pigmented rice varieties, including black, purple, and red rice, are rich in pigments and nutrients deposited in their bran layers [12].

This research focuses on utilizing red rice flour (RRF) as a substitute for wheat flour in various ratios to develop healthier cookies. Red rice, characterized by its red bran layer, is rich in iron, fiber, vitamins, and other essential nutrients [13-15]. Previous studies have shown that pigmented rice varieties, including red rice, have higher dietary fiber content than non-pigmented rice [16, 17]. However, the substitution of RRF in cookies is expected to alter their textural qualities due to the higher content of dietary fiber [18].

The lack of awareness and limited market access for pigmented rice pose challenges to its production and consumption. Moreover, there is limited research on the nutritional composition of pigmented rice in Sabah, Malaysia, where upland rice cultivation predominates due to geographical constraints [19]. Addressing these gaps, this study aims to produce cookies from RRF to increase market awareness of pigmented rice in Sabah, promote its cultivation, and contribute to achieving self-sufficiency in rice production as outlined in the National Agrofood Policy (NAP) 2021-2030. By producing cookies from RRF, this study aims to align with NAP 2.0's objectives of strengthening the domestic market, developing demand-driven products, and capitalizing on local specialty rice varieties to drive growth in the agri-food sector. Furthermore, this research responds to changing consumer dietary preferences by offering healthier, nutrient-rich cookie options while showcasing the unique attributes of pigmented rice to the consumer.

MATERIALS and METHODS

Raw Materials

The raw materials used in preparing the cookies included all-purpose flour (Bake with Yen, 9.8% protein content, 11% moisture content), red rice (Pasar Besar, Kota Kinabalu), unsalted butter (Ausicows, Bake with Yen), granulated sugar (Central Sugar Refinery, Bake with Yen), icing sugar (Namye, Bataras), eggs, and salt (E&G Food Ingredient, 99 Speedmart).

Preparation of Red Rice Flour

The procedure for preparing RRF was adapted from Bolarinwa et al. [5]. Initially, red rice grains were thoroughly washed and cleaned under tap water for five minutes to ensure the removal of dust and dirt particles. After draining, rice grains were dried in a drying cabinet (Thermoline Scientific TD-78T-SD, Australia) at 40°C for a minimum of 12 hours until the moisture content reached below 10%. Once dried, red rice grains were ground into RRF using a Waring blender (Panasonic MX-898, Malaysia) at low speed for five minutes, with intermittent scraping of residue from the blender walls at one-minute intervals. Subsequently, RRF was sifted using a sieve shaker (Endecotts Ltd., UK) to achieve a consistent particle size of less than 250 µm. Figure 1 depicts the photographs of RRP after washing, drying and milling processes.

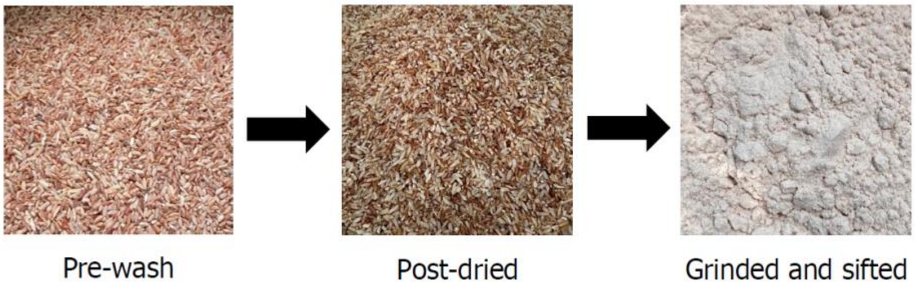

Figure 1. The photographs of RRP after washing, drying and milling processes

Formulation of Cookies

The cookie formulation incorporating RRF was adapted from Klunklin and Savage [11] with minor adjustments. The experimental cookies were prepared by replacing all-purpose flour with RRF at various levels: 20%, 40%, 60%, 80%, and 100% of the total flour weight. Table 1 presents the formulation of cookies substituted with RRF.

Table 1. Rice flour cookies formulations

Ingredient	Control	F1	F2	F3	F4	F5
All-purpose flour (%)	100	80	60	40	20	0
Red rice flour (%)	0	20	40	60	80	100
Butter+	50	50	50	50	50	50
Granulated sugar+	30	30	30	30	30	30
Icing sugar+	20	20	20	20	20	20
Egg+	20	20	20	20	20	20
Salt+	1	1	1	1	1	1

+Baker's percentage

Preparation of Cookies

The procedure for preparing red rice cookies was adapted from Zouari et al. [20] with slight modifications. Firstly, the butter was softened at room temperature and creamed with granulated sugar and icing sugar using a kitchen mixer (Panasonic, Malaysia) until smooth and pale in color. Beaten egg liquid was then added gradually, ensuring thorough mixing between each addition. Sifted flour and salt were gently folded into the mixture to prevent gluten formation. The dough was rolled out to a thickness of 6 mm, chilled in the freezer for 20 minutes, and then cut into shapes using a 5cm diameter cookie cutter. The cookies were baked in a commercial oven (Sinmag, Malaysia) at 150°C for 15 minutes, cooled on a wire rack for 30 minutes, and finally stored in zip-lock polyethylene bags at room temperature before analysis.

Sensory Evaluation

The sensory evaluation of the cookies was conducted at the Sensory Laboratory within the Faculty of Food Science and Nutrition, UMS, Malaysia. Panellists were recruited from the faculty staff and students through advertisements, and all participants provided informed consent. To ensure anonymity, the cookies were coded with three-digit numbers, permutated, and randomly served to panellists on trays. The panel evaluated the six formulations, with a total of 60 untrained panellists participating in the hedonic tests. Panellists assessed product attributes including appearance, color, aroma, taste, crispness, and overall acceptability using a nine-point hedonic scale ranging from 1 ("dislike extremely") to 9 ("like extremely") [21]. Sensory evaluation was conducted using printed questionnaires

Proximate Composition, Dietary Fibre and Total Energy

The proximate analysis of the samples was conducted according to the AOAC method [22] to determine their moisture, crude protein, crude fat, crude fiber, and ash content. Moisture content was determined by subjecting the samples to oven drying at 105°C until a constant weight was achieved. Crude protein content was assessed using Kjeldhal method (Kjeltex System-Texator), where the nitrogen value was converted to protein using a factor of 6.25. The crude fat content was determined using the Soxhlet system (Soxtec System-Texator), while carbohydrate content was calculated using the difference method. Ash content was determined by dry-ashing the samples in a furnace at 550°C for 24 hours. Total dietary fiber was evaluated using a Megazyme TDF kit [23]. The calorific content (kcal/100g) of the samples was calculated by multiplying the crude protein, crude fat, and available carbohydrate contents by factors of 4, 9, and 4, respectively.

Hardness Measurement

The hardness test to assess the breaking strength of the cookies was adapted from the methodology outlined by Jauharah et al. [24]. For this test, a texture analyzer (Stable Micro Systems, UK) was equipped with a 3-point bending rig (HDP/3PB) was utilized, operating at specific parameters: a pre-test speed of $1 mms^{-1}$, a test speed of $3 mms^{-1}$, with force measured at a distance of 5 mm and a trigger force of 50g was set to ensure accurate measurement of the cookies' hardness.

Color Analysis

The color characteristics of the cookies were assessed using a colorimeter (Hunterlab ColorFlex EZ, Reston) following the method described by Nielsen [25]. The Hunter color solid measures three dimensions: *L, a,* and *b.* The *L* value represents lightness, where a value of 100 indicates white color and a value of 0 indicates dark color. The *a* value indicates the red (+) or green (−) coordinate, while the *b* value indicates the yellow (+) or blue (−) coordinate.

Aspect Ratio and Bulk Density Determination

The aspect ratio of the cookies was determined using the length or diameter and the width or thickness of the cookies, following the methods described by AACC [23]. The bulk volume of the cookies was measured using the green beans displacement method, adapted from Mir et al. [26].

Consumer Study

In this study, 100 respondents were randomly selected from the general public, representing users or frequent users of the product. The consumer study was conducted at Padang Merdeka Kota Kinabalu (Sabah, Malaysia). Participants were asked to evaluate sensory attributes such as color, aroma, taste, texture, and overall acceptability.

Statistical Analysis

The experimental data collected from the nine-point hedonic test for the best formulation of red rice cookies were statistically analyzed using a one-way ANOVA with a completely randomized design. The mean values obtained were further analyzed using Tukey's honestly significant difference (HSD) test for a multicomparison of means. A t-test was used to analyze the results of the two samples. A significance level of $p<0.05$ was applied. Frequency analysis was utilized to analyze the data obtained from the consumer study. All statistical analyses were conducted using SPSS Statistics version 28.

RESULTS and DISCUSSION

Sensory Evaluation

Table 2 shows the sensory characteristics of the control cookie and different formulations of red rice cookies. Cookies achieving a score of 5 or higher were deemed acceptable, as noted by Yildiz and Gocmen [27], while a mean score of 7 or above typically indicates highly satisfactory sensory quality, making it a reliable benchmark for the "target" attribute [28]. Color plays a pivotal role in food acceptability and palatability [29], significantly influencing consumer preference and purchase decisions for baked goods [30]. Consumers often gauge food quality based on its color, which forms their initial impression and serves as a quality indicator [31].

Table 2. Sensory characteristics of control cookies and different formulations of red rice cookies

Attributes	Control	F1	F2	F3	F4	F5
Color	$7.11±2.14^{a}$	$6.79±2.01^{a}$	$6.57±1.87^{a}$	$6.48±1.83^{a}$	$6.41±2.01^{a}$	$6.16±2.01^{a}$
Aroma	$6.56±2.17^{a}$	$6.67±2.07^{a}$	$6.63±1.91^{a}$	$6.48±2.04^{a}$	$6.19±1.93^{a}$	$6.22±1.97^{a}$
Taste	$7.22±1.94^{a}$	$6.90±1.94^{ab}$	$7.02±2.07^{a}$	$6.84±2.15^{abc}$	$5.84±2.26^{bc}$	$5.79±2.20^{c}$
Crispness	$7.16±2.02^{a}$	$7.10±2.04^{a}$	$7.21±1.83^{a}$	$6.78±1.98^{ab}$	$5.89±2.28^{bc}$	$5.70±2.15^{c}$
Overall acceptability	$7.11±1.86^{a}$	$6.90±1.88^{a}$	$7.00±1.92^{a}$	$6.75±2.03^{ab}$	$5.86±2.10^{b}$	$5.87±2.18^{b}$

Data expressed as mean ± standard deviation, (n=63). Mean values in the same row with different superscripts are significantly different with $p<0.05$. Sample details: A = Control, 100% wheat flour; B = 20% substitution red rice flour, C = 40% substitution red rice flour, D = 60% substitution red rice flour, E = 80% substitution red rice flour, F = 100% substitution red rice flour.

Based on the mean scores for color presented in Table 2, no notable differences were found in color acceptability between the control cookie and any of the red rice cookie samples. This differs from Klunklin and Savage's [11] findings, where substituting up to 50% resulted in significant color variation. However, in our investigation, even with a complete substitution of RRF, color acceptability remained unchanged. The absence of a distinct red hue in the natural beige color of RRF could indeed contribute to this observation. Washing raw rice grains before processing is a common practice for hygiene, but it also removes aleurone layers containing red pigments like anthocyanins and proanthocyanins [32]. Thus, the resulting RRF may closely resemble unbleached white flour in color. Consequently, it can be inferred that RRF substitution does not significantly alter cookie color acceptability.

Aroma, along with taste, texture, color, and warmth, significantly influences food acceptance and appreciation [33]. However, based on the mean scores obtained for aroma in Table 2, RRF substitution levels from 20% to 100% did not significantly affect aroma acceptability compared to the control cookie. This indicates high acceptability among panelists for various levels of wheat flour substitution with RRF. This contrasts with Klunklin and Savage's [11] study, where all levels of purple rice flour substitution (20%, 40%, 60%, 80% and 100%) resulted in significant aroma differences compared to the control wheat cookie. The lack of aroma impact in our study may stem from the aromatic compound content in RRF itself. Processing methods, including rice washing, roasting, milling, and storage, can affect aromatic volatile compounds in rice flour. Washing rice grains before drying and grinding significantly reduces volatile content [34]. Additionally, the removal of the lipid-rich bran layer during milling reduces lipid breakdown products, impacting aroma. Storage conditions can also alter rice aroma over time.

Taste is a critical factor in consumer acceptance, with the four primary taste qualities being sweet, salty, sour, and bitter [31]. In our study, formulations F4 and F5 showed a significant taste difference compared to the control sample and F2. However, these formulations received the lowest taste scores, indicating lesser preference among panelists. Formulations F1, F2, and F3 did not significantly differ from the control, with F2 being the closest to the control sample.

Crispness, describing cookie hardness, affects textural preference [35]. Mean scores for F4 and F5 were significantly lower than the control and F1 – F3, indicating undesired crispness. Additionally, crispness decreased significantly as RRF substitution levels exceeded 60%. This trend is consistent with previous studies on flour substitutions [20]. Overall acceptability reflects a blend of sensory attributes in a product [36]. Mean scores for overall acceptability decreased as RRF substitution levels exceeded 60%. However, formulations F1, F2, and F3 did not significantly differ from the control, with F2 being the closest to the control sample.

Selection of Best Formulation

Color, flavor, aroma, and texture, including hardness, crispiness, and dryness, are critical sensory attributes defining the quality of cookies [35]. Identifying the optimal formulation involves comparing it to the control cookie, aiming for similarity and achieving high mean scores across sensory attributes. Analysis of Figure 2 and preceding discussions reveals that formulation F2 of the red rice cookie closely resembles the control cookie in terms of taste, crispness, and overall acceptability. Notably, these attributes attained mean scores exceeding seven, indicating exceptionally satisfactory sensory quality. Additionally, feedback from the hedonic test highlighted that the cookie with a 40% substitution level was perceived as the most palatable by the majority of respondents. Therefore, based on these findings, formulation F2 with a 40% substitution level of RRF emerges as the optimal choice among the various substitution levels tested. Thus, formulation F2 was chosen for further evaluation through proximate analysis, physical assessment, and consumer study.

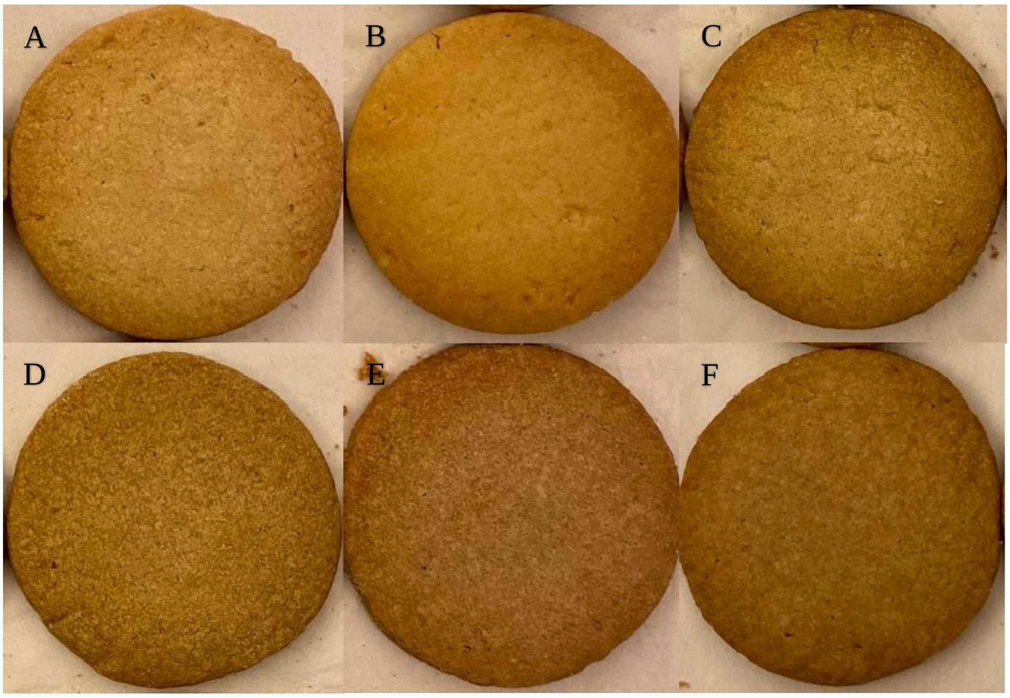

Figure 2. Cookies made of wheat flour and red rice flour (RRF) with different levels of substitution (A: control, B: 20% substitution RRF, C: 40% substitution RRF, D: 60% substitution RRF, E: 80% substitution RRF and F: 100% substitution RRF)

Proximate Composition

Table 3 presents the nutritional compositions of red rice flour, the control cookie, and formulation F2. A notable finding from Table 3 is the significantly higher moisture content in the control cookie compared to the F2 red rice cookie. This disparity can be attributed to the inherently lower moisture content of RRF. Consequently, the reduced moisture content in F2 can be attributed to the characteristics of RRF itself. Contrary to the findings in this study, Klunklin and Savage [11] reported a linear increase in moisture content with higher concentrations of purple rice flour. This discrepancy could be due to differences in flour particle size, with coarser particles, as observed in RRF, possessing lower water-holding capacity. Additionally, the dryland soil conditions of upland rice cultivation may limit mineral availability, possibly contributing to the lower ash content in RRF [37]. Although it was anticipated that RRF would exhibit higher mineral content, including iron and potassium, the ash content did not significantly differ from that of refined wheat flour.

Moreover, the crude protein content in the control cookie was significantly higher than that of F2. This difference is attributable to the lower protein of the rice flour than wheat flour. Furthermore, the crude fat content did not significantly differ between the control cookie and F2, despite RRF exhibiting a higher fat content than refined wheat flour. Regarding crude fibre content, F2 displayed significantly higher levels compared to the control cookie. This discrepancy is consistent with the higher fibre content of RRF compared to refined wheat flour [37]. Furthermore, available carbohydrate content did not significantly differ between the control cookie and F2. However, RRF exhibited higher available carbohydrate content compared to refined wheat flour, aligning with previous research [38, 39]. This higher carbohydrate content in RRF may contribute to the carbohydrate content of F2.

Table 3. Nutritional compositions of red rice flour, control cookie and F2 red rice cookie

Composition (%)	Red rice flour	Control	F2
Moisture	8.98±0.38	3.6±0.14^{a}	2.05±0.07^{b}
Ash	0.58±0.05	0.47±0.03^{a}	0.55±0.05^{a}
Crude protein	7.58±0.30	7.14±0.11^{a}	6.15±0.10^{b}
Crude fat	1.62±0.30	22.30±1.58^{a}	20.35±0.34^{a}
Crude fibre	2.15±0.11	1.13±0.09^{b}	1.90±0.11^{a}
Total dietary fibre	3.75±0.32	1.90±0.14^{b}	3.02±0.21^{a}
Carbohydrate	75.34±0.10	63.46±1.77^{a}	65.97±0.29^{a}
Energy (kcal)	353.81±2.53	486.86±7.03^{a}	477.69±2.25^{a}

Data expressed as mean ± standard deviation, (n=3). Mean values in the same row with different superscripts are significantly different with p<0.05. F2 = 4% substitution red rice flour.

Total Dietary Fibre

The total dietary fiber content in the F2 was significantly higher compared to that of the control cookie (Table 3). These findings align with the results reported by Klunklin and Savage [11], where the substitution of purple rice flour significantly increased the total dietary fiber content in purple rice cookies compared to control wheat cookies. Dietary fiber encompasses the indigestible components of food, primarily derived from plant cell wall material and consisting mainly of polysaccharide molecules. Major constituents include cellulose, hemicelluloses, lignin, and other non-starch polysaccharides like pectin. According to AACC [23], dietary fiber refers to edible plant parts or similar carbohydrates that resist digestion and absorption in the small intestine, undergoing complete or partial fermentation in the large intestine. Adequate dietary fiber intake from diverse sources is associated with reduced colon cancer risk and helps maintain healthy blood lipid levels, lowering the likelihood of obesity, hypertension, and cardiovascular disease. Given that the total dietary fiber content in the F2 significantly exceeds the threshold required for a nutrition claim, consideration may be given to such a claim. As per the Fifth A Schedule (Regulation 18 c) of Malaysia Food Regulations 1985, products must contain at least 3g of total dietary fiber per 100g (solids) to claim a source of total dietary fiber. With the F2 red rice cookie containing 3.02g of total dietary fiber per 100g, it meets the criteria for making such a claim.

Total Energy Content

There was insignificant difference in the energy contents between the control and the F2 red rice cookies (Table 3). Although not statistically significant, the slight decrease in energy content of the F2 red rice cookie could be attributed to its lower crude protein and crude fat content compared to the control cookie.

Hardness

The texture of cookies, particularly their hardness, is a crucial aspect influenced by various factors [27]. As depicted in Table 4, the hardness was significantly greater for the control cookie compared to the F2. This aligns with findings from Klunklin and Savage [11], where incorporating different levels of purple rice flour resulted in a notable reduction in cookie hardness. Additionally, cookies substituted with coarse-grained short-grain rice exhibited decreased hardness compared to the control wheat cookie, as observed by Mancebo et al. [40]. Chung et al. [41] similarly reported that all cookies containing rice flour required less force to snap compared to the control cookie.

Several factors may contribute to the decreased hardness of substituted cookies. Firstly, changes in the dough matrices due to reduced gluten content could play a role. The hardness of cookies relies on the structure of the composite matrix comprising gluten protein aggregates, lipids, sugars, and ungelatinized starch granules. Therefore, substituting wheat flour with gluten-free rice flour reduces the gluten protein content in the dough, resulting in a less rigid composite matrix and decreased cookie hardness [41]. Secondly, the use of flours with different particle sizes could influence hardness. Research by Mancebo et al. [40] indicates that cookies made from fine-grained flour require higher peak force compared to those made with coarse-grained flour. While the RRF used in this study was ground and sieved to achieve a consistent particle size of <250μm, most cookie flours typically have an average particle size of around 50 μm, with fewer than 10% larger than 130 μm. Consequently, the coarser particle size of RRF used in baking F2 may contribute to their lower hardness compared to the finer wheat flour used in the control cookies.

Color

Color plays a pivotal role in influencing consumer preferences and purchasing decisions when it comes to bakery products. In the case of the F2, notable differences were observed compared to the control cookie. The F2 exhibited significantly lower lightness, higher redness, and lower yellowness than the control cookie (Table 4). The lightness of a cookie is not only influenced by the Maillard reactions occurring during baking but also by the color of the flour used, as noted by Mancebo et al. [40]. The darkened color observed in cookies can result from caramelization of sugars in the recipe or the Maillard reaction, both of which contribute to the browning effect during baking. The incorporation of RRF in the cookie formulation may lead to a darker surface compared to control cookies, which typically exhibit higher lightness values. Moreover, the increased redness observed in the F2 could be attributed to the presence of red pigments naturally found in the husk of red rice. Conversely, the decrease in yellowness of the F2 may be due to the degradation of unstable yellow compounds present in RRF during the baking process.

Table 4. Physical characteristics of red rice cookie

Parameter	Control	F2
Hardness (N)	35.07±0.37[a]	28.45±0.61[b]
L*	70.67±0.04[a]	57.22±0.02[b]
a*	10.05±0.03[a]	13.42±0.01[b]
b*	32.69±0.03[a]	30.74±0.13[b]
Aspect ratio	5.70±0.10[a]	6.43±0.15[a]
Bulk density (g/mL)	0.77±0.02[a]	1.15±0.04[b]

Data expressed as mean ± standard deviation, (n=3). Mean values in the same row with different superscripts are significantly different with $p<0.05$. F2 = 40% substitution red rice flour.

Aspect Ratio

The aspect ratio of cookies serves as a crucial quality indicator, with higher values generally associated with desirable cookie characteristics, such as a larger diameter and thinner thickness [42]. The aspect ratio was notably higher for the F2 compared to the control cookie (Table 4). Similarly, Chung et al. [41] reported a significant increase in the aspect ratio of cookies with rice flour incorporation. Research by Mancebo et al. [41] revealed a positive correlation between particle size and aspect ratio (r= 0.75; 99%) and a negative correlation between aspect ratio and water holding capacity (WHC) (r= 0.47; 95%). Finely ground flours demonstrated higher water binding and holding capacities compared to coarse-grained flours. This suggests that flours with finer particle sizes tend to have higher WHC and water binding capacities, resulting in lower spread ratios. The spread ratio of cookies is also affected by dough viscosity. Flours possessing high water holding capacity WHC and water binding capacities tend to limit the availability of water for sugar dissolution in the dough, consequently resulting in elevated initial viscosity.

Bulk Density

Referring to Table 4, the bulk density exhibited a significant increase in the F2 compared to the control cookie. This trend aligns with findings from other studies [43, 44], where bulk density showed a significant increase with higher formulations of jering seed flour. Similarly, research by Zouari et al. [20] indicated a significant increase in bulk density when wheat flour was substituted with sesame flour. Bulk density determination holds significance as it serves as a parameter for determining storage, transportation, and packaging considerations for cookies [45]. The variance in bulk density can be attributed primarily to differences in particle size and flour density [43].

Consumers Study

To evaluate consumers' acceptance towards the 40% substitution red rice cookie, a consumer study was conducted. A total of 100 respondents were chosen randomly during the event, with which 55 of them were female, and 45 of them were male. The respondents collected consisted of a wide range of ethnic groups, which include Bisaya, Bajau, Chinese, Dusun, Iban, Lundayeh, Malay, Murut, Sea Dayak and Toraja. In the consumer study conducted, respondents were presented with a range of attributes to evaluate their preferences and perceptions regarding the red rice cookie with a 40% substitution rate. These attributes included color, aroma, taste, texture, and overall acceptability. A significant proportion of respondents, constituting over 80% of the total participants, exhibited a high level of acceptance toward the red rice cookie with 40% substitution (Figure 3). This indicates that the majority of individuals who participated in the study found this particular variation of the cookie to be appealing across multiple sensory dimensions. The high level of acceptance observed among participants underscores the favorable sensory characteristics and overall palatability of the red rice cookie with 40% substitution. These findings suggest that the incorporation of red rice flour into the cookie formulation at this specific substitution rate has successfully met or exceeded consumer expectations, eliciting positive responses across various attributes such as color, aroma, taste, texture, and overall acceptability.

CONCLUSION

The study revealed that incorporating 40% RRF led to reductions in moisture and crude protein content while increasing crude fiber and total dietary fiber content in the cookies. Physical analysis showed significant changes in hardness, color, aspect ratio, and bulk density of the best formulation (F2) compared to the control. However, the sensory evaluation indicated no significant differences between the F2 red rice cookie and the control, suggesting that the 40% substitution of RRF did not negatively impact sensory characteristics according to the panelists. Through sensory evaluation, the red rice cookie with 40% substitution emerged as the best formulation, closely resembling the taste, crispness, and overall acceptability of the control cookie, with no significant differences observed in sensory attributes. The F2 received higher palatability ratings based on comments from the sensory evaluation forms. In conclusion, this study presents a promising approach to enhance the cookies' nutritional profile by increasing dietary fiber content, addressing the deficiency typically found in cookies made with wheat flour. However, further research is needed to optimize the formulation to reduce fat content and produce lower-fat cookies.

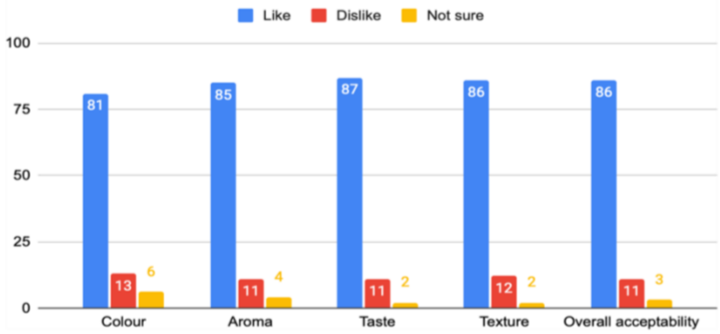

Figure 3. Consumers' acceptance towards sensory attributes of 40% substitution red rice cookie (n=100)

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