Physicochemical and sensory characteristics of iron rich macarons based on red rice and moringa leaf flour

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ABSTRAK

Latar Belakang: *Remaja putri di Indonesia beresiko tinggi mengalami anemia akibat kekurangan zat besi dengan prevalensi 32,0%. Konsumsi pangan sumber zat besi dapat mencegah anemia, misalnya beras merah dan daun kelor. Namun pengembangan kukis dari beras merah dan daun kelor masih terbatas, termasuk pada produk macaron yang terbuat dari tepung almond dan putih telur.*
Tujuan: *Penelitian ini bertujuan untuk menemukan formula, menguji kadar proksimat dan zat besi, serta tingkat kesukaan remaja terhadap macaron substitusi tepung beras merah dan tepung kelor.*
Metode: *Penelitian RnD untuk menguji kadar proksimat dan kadar besi. Macaron yang diuji adalah F_0 (0% tepung beras merah, 0% tepung kelor), F_1 (60% tepung beras merah, 0% tepung kelor), dan F_2 (60% tepung beras merah, 3% tepung kelor). Analisis statistik menggunakan uji One-Way Anova dan uji lanjutan Tukey HSD.*
Hasil: *Macaron dengan substitusi 60% tepung beras merah dan 3% tepung kelor memiliki kandungan gizi per 100 g berupa 3.28±0.11 g air, 1.58±0.28 g abu, 19.56±0.00 g lemak, 18.21±0.54 g protein, 70.61±0.71 g karbohidrat, dan 11.49±0.05 mg zat besi. Kadar zat besi macaron per porsi (45 gram) memenuhi 34.47% kebutuhan zat besi remaja sehingga dikategorikan sebagai pangan tinggi zat besi. Hasil uji hedonik menunjukkan macaron substitusi 60% tepung beras merah dan 3% tepung kelor disukai oleh remaja dan berbeda nyata dengan produk acuan.*
Kesimpulan: *Macaron substitusi 60% tepung beras merah dan 3% tepung kelor dikategorikan sebagai kukis tinggi zat besi karena dapat memenuhi 34.47% angka kecukupan zat besi remaja sehingga berpotensi sebagai pangan fungsional untuk mencegah anemia pada remaja.*

Kata kunci: *macaron; remaja; tepung beras merah; tepung kelor; zat besi*

ABSTRACT

Background: *Adolescent girls in Indonesia face a high risk of iron-deficiency anemia, with a prevalence of 32%. Anemia is characterized by low hemoglobin or red blood cell levels, and consuming iron-rich foods can help prevent it. Moringa leaves contain 28.2 mg of iron, while macarons are cookies made from almond flour and egg whites. Substituting almond flour with red rice and moringa flour is expected to increase the product's iron content.*
Objectives: *This study aims to analyze the proximate composition, iron content, and acceptability of macarons substituted with red rice flour and moringa flour.*
Methods: *Research and Development was conducted to test the proximate composition and iron content. The macarons tested were F_0 (0% red rice flour, 0% moringa flour), F_1 (60% red rice flour, 0% moringa flour), and F_2 (60% red rice flour, 3% moringa flour). Statistical analysis was performed using One-Way ANOVA and Tukey HSD.*
Results: *Macarons with 60% red rice flour and 3% moringa flour contain 3.28±0.11 g water, 1.58±0.28 g ash, 19.56±0.00 g fat, 18.21±0.54 g protein, 70.61±0.71 g carbohydrates, and 11.49±0.05 mg iron per 100 g. A 45 g serving provides 34.47% of adolescents' daily iron needs, classifying the product as iron-rich. Hedonic testing showed that this formula was preferred by adolescents and significantly different from the reference product*
Conclusions: *Macarons with 60% red rice flour and 3% moringa flour are categorized as iron-rich cookies because they meet 34.47% of adolescents' iron requirements, indicating their potential as a functional food to help prevent anemia.*

Keyword*:* *adolescents; iron; macaron; moringa flour; red rice flour*

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INTRODUCTION

Adolescence is a transitional phase from childhood to adulthood between the ages of 10 and 18 that requires special attention in terms of health and nutritional status (1) (2)Adolescence teenagers tend to have unhealthy eating habits because they like to consume foods high in sugar and salt, but do not consume enough vegetables and fruits (1). Factors that can influence eating patterns in adolescents include knowledge, gender, environment, the internet, income level, and food sources(1). Unhealthy eating patterns and low intake of essential nutrients such as iron contribute to high rates of anemia among adolescent girls. Adolescent girls are at high risk of anemia caused by several conditions, such as blood loss during menstruation, iron deficiency, and early pregnancy (2).

Anemia is a condition in which the body lacks hemoglobin or red blood cells that are far below normal levels (3). The prevalence of anemia in women is 27.2% higher than in men (20.3%), while in adolescents aged 15-24 years it is 32.0% (4). Anemia in

adolescent girls is caused by low iron intake and other nutrients such as vitamin A, vitamin C, folate, riboflavin, and vitamin B12 (5). Protein deficiency can also cause anemia. Protein plays a role in transporting iron to the spinal cord for the formation of hemoglobin (6). Anemia in adolescents causes serious effects on the immune system, concentration, fitness, and productivity. Anemia in adolescent girls poses a high risk when they become mothers, potentially leading to premature birth, risk of death during childbirth, and low birth weight babies (5).

Consuming iron-rich foods can help treat anemia. Iron-rich foods are divided into two categories: animal-based and plant-based (7). Animal-based foods that contain iron include eggs, chicken liver, red meat, and fish (8). Plant-based foods that contain iron include various nuts, seaweed, brown rice, and moringa leaves. One food that can be used as a source of iron is red rice flour and moringa leaves (9). Red rice (*Oryza nivara*) is obtained from a milling process without polishing, so it still has its brand (10). In 100 g of red rice flour, there are 352 kcal, 0.9 g of fat, 7.3 g of protein, 76.2 g of carbohydrates, 4.2 milligrams of iron, and 0.8 g of fiber (11). Moringa leaves (*Moringa oleifera*) belong to the Moringaceae family, originating from the western and sub-Himalayan regions (12). Moringa leaves are known as the “Miracle Tree” because they are one of the superfoods rich in nutrients. In 100 g of moringa flour, there are 205 kcal, 27.1 g of protein, 2.3 g of fat, 38.2 g of carbohydrates, and 28.2 milligrams of iron (13,14). Moringa powder is known for its high iron (Fe) content.

Efforts to increase iron intake in adolescents can be done by substituting food products, such as bakery products. Bakery products are food products made from processed flour, eggs, sugar, and other ingredients (15). Baked goods include bread, cake, pastry, and cookies. Cookies are small baked goods (15). Cookies are made from soft dough, are high in fat, crispy, and have a less dense texture (16). Based on their texture, cookies are classified into crispy, chewy, and soft cookies (15). Macarons are known as cookies made from egg whites, almond flour, and sugar, with a chewy texture (17). Macarons are desserts that were first made in Italy with a crunchy texture. Based on the method used to make them, macarons are divided into French meringue method, Italian meringue method, and Swiss meringue method (18). Macarons have the advantages of a unique texture, being gluten-free, and having high selling value. However, macarons have the disadvantages of being difficult to make and prone to failure, the raw materials used are relatively expensive, they do not last long, and environmental conditions greatly affect the final result of the macaron shell (18).

Macarons have the potential to be developed in Indonesia despite various challenges in the manufacturing process. The Indonesian confectionery market is projected to reach USD 7.776 billion by 2025, with an annual consumption of 4.5 kg per person (19). Additionally, data from Euromonitor (20) reveals that the high demand for bakery products in Indonesia amounts to USD 5.3 billion. Public interest in macarons is evident on the e-commerce platform Shopee, where some stores sell over 10.000 pieces of macarons (21–23). This highlights a significant opportunity to develop innovative products such as macarons using substitutes like red rice flour and moringa flour.

The development of cookies with red rice flour and moringa leaf substitutes has been published. Research by Zaddana et al (24) reports that biscuits made with a combination of red rice flour and moringa flour contain 5.74 g of fiber and 5.28 mg of iron. Therefore, the biscuit product is categorized as a source of fiber and iron (25). Research by Yulia Nabilla et al (9) reports the development of biscuits made with a mixture of purple sweet potato flour, soybeans, moringa leaves, and mackerel, containing 11.18 g of protein and 2.73 g of iron. Therefore, the product can be categorized as a food source of protein and iron (25). Khofifah et al (26) also reported that the development of moringa leaf biscuits can affect hemoglobin levels in adolescent girls after intervention, namely 12.9 g/dl. However, to date, the development of macarons with red rice flour and moringa leaf substitution has not been reported. Therefore, this study aims to determine the formula, test the proximate composition and iron content, as well as the acceptability of macarons made with red rice flour and moringa leaf flour among adolescents. The results of this study are expected to provide healthy iron-rich cookies for the prevention of anemia in adolescents.

MATERIALS AND METHODS

The ingredients used in this study were almond flour, red rice flour, moringa flour, Gulus brand icing sugar, Gulaku brand caster sugar, egg whites, and Tulip brand chocolate filling. The equipment used in this study included scales, a sieve, a mixer, a dough bowl, a spatula, a silpat, a piping bag, and an electric oven. This study was conducted from January to June 2025. The production process was carried out at the Chemistry Laboratory of the Faculty of Engineering, Yogyakarta State University. Proximate analysis and iron content testing were conducted at the PAU Center for Food and Nutrition Studies, Gadjah Mada University.

Determination of macaron recipes with red rice flour and moringa flour substitutes

***a. Define* stage**

In the define stage, three macaron recipes from different sources were tested. The selected macaron recipe was used as a reference recipe to be substituted with red rice flour and moringa flour. Macaron shells have unique characteristics and a complicated manufacturing process (18). The accuracy of the raw material quantities and the technique used to mix the macarons affect the final result of the macarons (15) (15). The main ingredients in making macaron shells are almond flour, icing sugar, caster sugar, and egg whites. Macaron dough that is too moist causes the dough to be too flat and spread out (15).

b. *Design* stage

The design stage aims to determine the development recipe from the reference recipe selected in the define stage by substituting red rice flour and moringa flour. The amount of red rice flour substitution used is 20%, 40%, and 60%. The selected red rice flour substitution result is 60%. The next step is to add moringa flour at 1%, 3%, and 5% of the total amount of almond flour.

c. *Development* stage

The development stage was validated by the expert lecturer. There was a suggestion to replace the vanilla filling with chocolate filling.

d. *Dissemination stage*

The dissemination stage was conducted to determine the level of preference by 80 female teenage panelists. The results of the organoleptic test were conducted by 80 female teenage panelists aged 16-18 years.

The process of making macarons

The process of making macarons with red rice flour and moringa flour substitutes begins with weighing the ingredients using a scale accurate to 0.001 g. The next step is to beat the egg whites with caster sugar using a high-speed mixer until they reach a soft peak consistency. Then add the sifted dry ingredients, namely almond flour, icing sugar, red rice flour, and moringa flour. Mix the dough thoroughly using the folding technique until it falls into a ribbon shape. Put the dough into a piping bag, then pipe it onto a silpat. Let the dough rest for 45 minutes to 1 hour until the surface of the macarons is dry. Bake the macarons in an oven preheated to 135°C for 40-50 minutes. Remove the macarons once they have cooled and hardened. Next, fill the macarons with chocolate filling. The macaron making process can be seen in **Figure 1**.

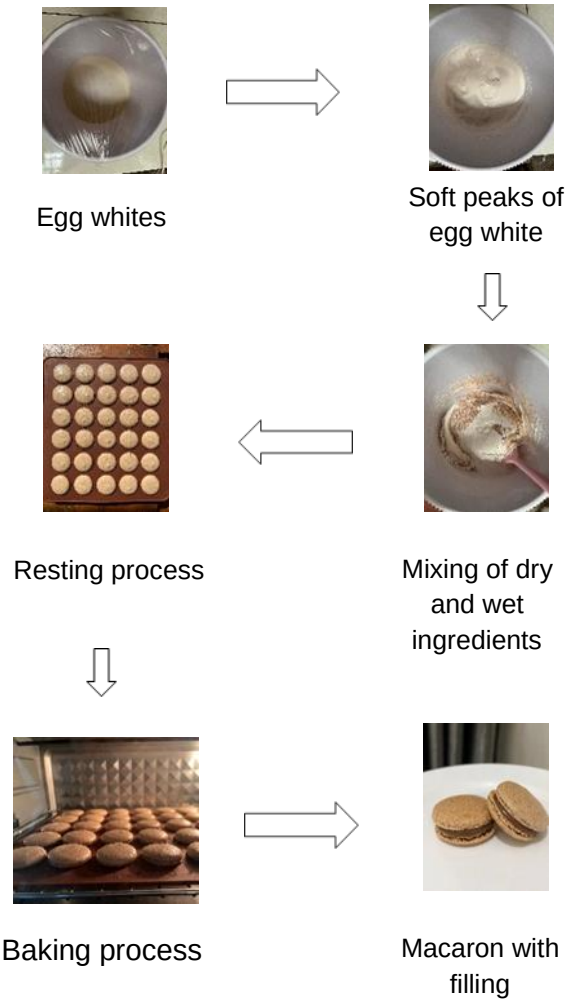

Figure 1. Process of making macarons substituted with red rice flour and moringa flour

Proximate analysis

Moisture content is measured using the gravimetric method. The equipment used is an analytical balance with a sensitivity of 0.1 mg and an oven. Moisture is determined by heating the sample in an oven at a temperature of 100–105°C until a constant weight is achieved. The weight measured is the moisture content of the sample.

Ash content is measured using the gravimetric method. The equipment used is an analytical balance with a sensitivity of 0.1 mg and an ash crucible. The macaron sample is incinerated until free of carbon, and the remaining ash is the ash content of the sample.

Fat content is measured using the Soxhlet method with Weibull modification. The equipment used is a Soxhlet extraction apparatus and a balance with a sensitivity of 0,1 mg. The reagents used are 8 N hydrochloric acid (HCl) (65%) and diethyl ether or petroleum ether at a temperature of 40–60°C. The macaron sample is hydrolyzed with hydrochloric acid (HCl) to release the bound fat. The fat is then extracted with diethyl

ether in a Soxhlet extraction apparatus. The diethyl ether is evaporated, and the fat residue in the Soxhlet flask is weighed

The protein content is measured using the Kjeldahl method (27). The equipment used is a 500 ml Kjeldahl flask, a distillation apparatus, and a scale with a sensitivity of 0,1 mg. The reagents used are concentrated sulfuric acid (H_2SO_4), anhydrous potassium sulfate (K_2SO_4), mercury oxide (HgO) or copper sulfate ($CuSO_4 \cdot 5H_2O$), 60% sodium hydroxide (NaOH), 0.1 N hydrochloric acid (HCl), 3% boric acid, and a mixture of blue and red metal indicators (1:2) in 95% ethanol. The sample was destroyed with concentrated sulfuric acid using potassium sulfate and mercury oxide as catalysts. The organic nitrogen in the sample was converted into ammonium ions and then distilled with the addition of sodium hydroxide. The nitrogen content in the sample was determined by standard acid titration.

The carbohydrate content was measured using the difference method, which involves subtracting 100% from the results of water, ash, fat, and protein.

Iron content testing

Iron content is measured using spectrophotometry. The equipment used includes a muffle furnace, Erlenmeyer flasks, porcelain crucibles, and a balance with an analytical sensitivity of 0.1 mg. The reagents used are HNO_3, ammonium thiocyanate, and distilled water.

Preference testing

Eighty female adolescents aged 10–18 years conducted a sensory test by filling out a form to determine the preference level of red rice flour and moringa flour substitute macarons. The parameters measured were color, aroma, taste, texture, and overall characteristics, with scores ranging from 1 = strongly dislike, 2 = dislike, 3 = somewhat like, 4 = like, and 5 = strongly like.

Data Analysis Techniques

Data were analyzed using SPSS 26 software. An ANOVA test was conducted, followed by a Tukey HSD test (significance level 0.05).

RESULTS AND DISCUSSIONS

Define stage

In the define stage, the best recipe was selected from three reference recipes. The recipes were obtained from books. The reference recipes were selected based on color, aroma, taste, texture, and overall product quality. The three reference recipes can be seen in **Table 1**.

Tabel 1. Reference Recipe for Macaron

Ingredients	Amount		
	Recipe A	Recipe B	Recipe C
Almond flour	100 g	165 g	125 g
Egg whites	80 g	115 g	100 g
Icing sugar	100g	165 g	200 g
Castor sugar	100 g	150 g	40 g

Source: Primarasa (A), Wayne Gisslen (B) (C)

Recipe A is sourced from Primarasa (18), recipe B and C sourced from Wayne Gisslen (15). Recipe B has the best shape among the three recipes. The crust is flat and thin, the taste is sweet, the color is the whitest, the aroma is sugary, and the texture is crispy and chewy. Therefore, the selected recipe at the define stage is Recipe B, sourced from Wayne Gisslen (15).

Design stage

In the design stage, the recipe selected in the previous stage (define stage) will be used as a reference in substituting the substitute ingredient, namely red rice flour, in the development of macarons. Recipe B, sourced from the book Professional Baking Seventh Edition by Wayne Gisslen, was selected as the reference recipe. The comparison of red rice flour substitution and moringa flour in the formula can be seen in **Figure 2**.

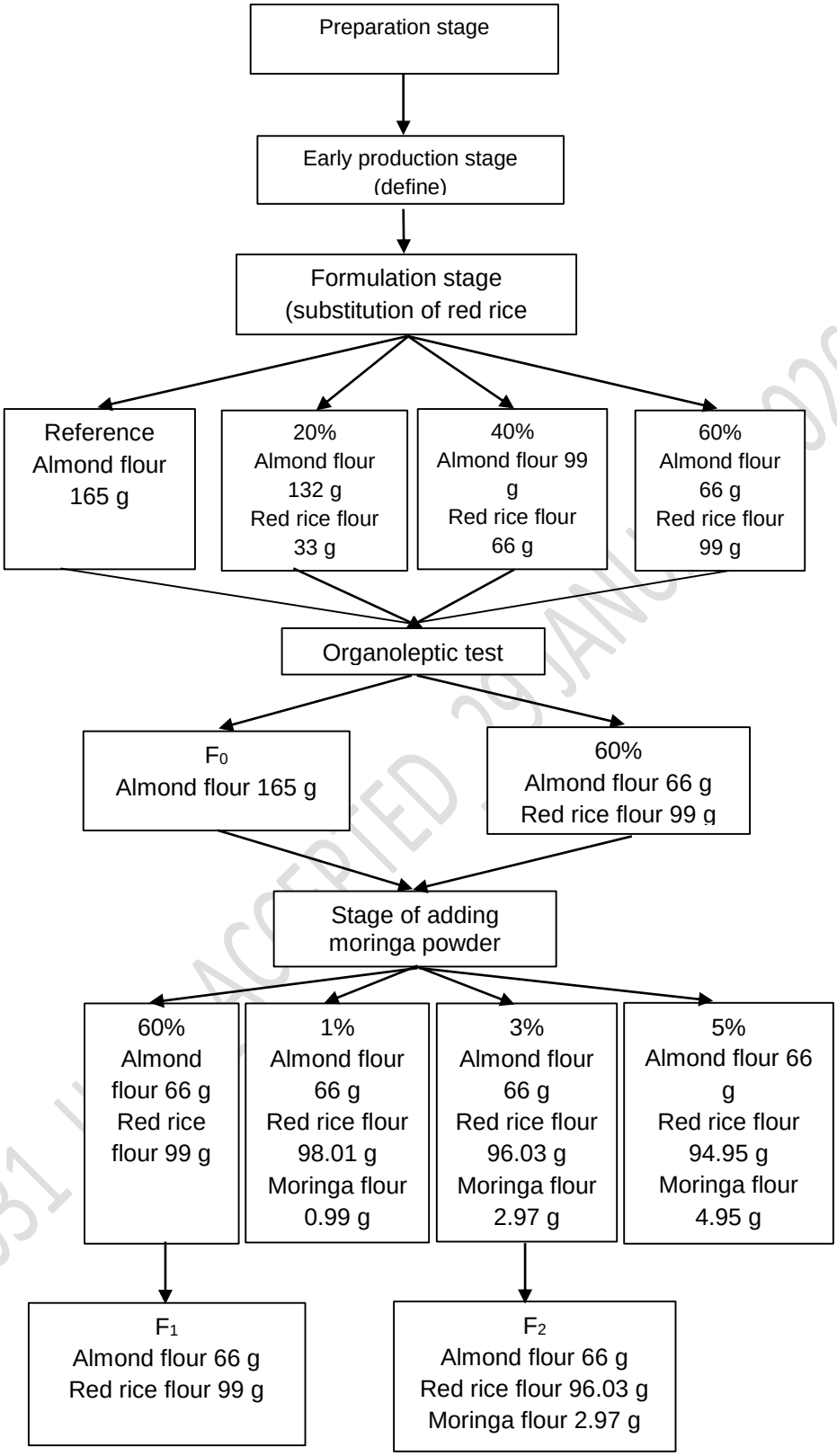

Figure 2. Comparison of red rice flour substitution and moringa flour in the formula

Macarons with 3% moringa flour have a balanced sweet and bitter taste, making them acceptable to validators. Meanwhile, macarons with 5% moringa flour have a taste that is too bitter. Therefore, the formula selected at the design stage is macarons with 60% red rice flour and a 3% substitution of moringa flour. After the product was selected, proximate analysis and iron content testing were conducted to determine the nutritional content of the macarons with a substitution of 60% red rice flour and 3% moringa flour.

Macaron recipe substituting 60% red rice flour and 3% moringa flour

A picture of the macaron product obtained from the 4D stage can be seen in **Figure 3**.

Figure 3. Macarons substituted with 60% red rice flour and 3% moringa flour

Proximate and iron content of macarons

Tabel 2. Proximate and iron content of macaron with red rice flour and moringa flour substitution

Proximate level	*Macaron*			
	F_0	F_1	F_2	p-value
Water Content %	3.76 ± 0.19[a]	2.58 ± 0.13[b]	3.28 ± 0.11[a]	0.009
Ash Content %	2.03 ± 0.01[a]	1.66 ± 0.09[a]	1.58 ± 0.28[a]	0.139
Fat Content %	26.04 ± 0.18[c]	19.56 ± 0.29[b]	6.33 ± 0.00[a]	0.000
Protein Content %	7.62 ± 0.60[b]	6.15 ± 0.04[a]	18.21 ± 0.54[c]	0.044
Carbohydrate Content %	60.57 ± 0.58[a]	70.06 ± 0.21[b]	70.61 ± 0.71[b]	0.001
Iron Content %	5.79 ± 0.05[c]	8.76 ± 0.09[b]	11.49 ± 0,05[a]	0.000
Energy (kcal)	186.73	186.21	236.95	

Description:

F_0 = Macaron without substitution of red rice flour and moringa flour

F_1 = Macaron substituted with 60% red rice flour and 0% moringa flour

F_2 = Macaron substituted with 60% red rice flour and 3% moringa flour

The highest moisture content was obtained from macarons without substitution of red rice flour and moringa flour (F0), while the lowest moisture content was obtained from macarons with 60% substitution of red rice flour and 0% substitution of moringa flour (F_1). This indicates that the substitution of red rice flour and moringa flour has a

significant effect on moisture content. Moisture content in food determines several important factors, namely acceptability, freshness, shelf life, chemical reactions, enzyme activity, and microorganism growth (28). When compared to SNI 2973:2022, the moisture content of macaron F_0, F_1, and F_2 is below 5% (29). Therefore, following SNI, macarons with the highest moisture content can cause undesirable changes. This is because high moisture content causes the growth of bacteria, fungi, and yeast. Several factors that affect the moisture content in macarons are the initial moisture content of the raw materials, the cooking process, the shape, the temperature, and the water evaporation during baking (30).

The highest ash content was obtained from macarons without substitution of red rice flour and moringa flour (F_0). Meanwhile, the lowest level was obtained from macarons with 60% red rice flour without moringa flour (F_1). This shows that substituting red rice flour can reduce the ash content in a food product. Macarons with 60% red rice flour and 3% moringa flour substitution (F_2) have a higher ash content than those with red rice flour substitutes (F_1). The ash content in food is influenced by environmental factors, raw materials, and temperature (31). When compared to Indonesian National Standard SNI 2973:2022, the ash content of macaron F_0, F_1, and F_2 is above 0,1, making it non-compliant with Indonesian National Standard (29).

The fat content of the macarons decreased. The highest fat content was obtained from macarons without red rice flour and moringa flour substitution (F_0). Meanwhile, the lowest fat content was obtained from macarons with 60% red rice flour and 3% moringa flour substitution (F_2). Adding fat to food can slow down the hardening of texture (making it softer) and enhance flavor (32). However, to date, there are no SNI standards regulating the fat content of cookies. The source of fat in macarons is almond flour.

The highest protein content was obtained from macarons without substitution of red rice flour and moringa flour (F_0). Meanwhile, the lowest protein content was obtained from macarons with 60% substitution of red rice flour (F_1). Macarons with 60% red rice flour and 3% moringa flour substituted (F_2) have a higher protein content than macarons substituting 60% red rice flour (F_1), but lower than macarons without red rice flour and moringa flour substitutions (F_0). In addition to raw materials, heating temperature also affects the protein content of food (33). When compared to Indonesian National Standard 2973:2022, the protein content of macaron F_0, F_1, and F_2 is > 4,5, thus complying with Indonesian National Standard (29).

The carbohydrate content of macarons increased. The highest carbohydrate content was obtained from macarons with 60% substitution of red rice flour and 3%

moringa flour (F_2). Meanwhile, the lowest carbohydrate content was obtained from macarons without substitutes for red rice flour and moringa flour (F_0). To date, there are no SNI standards regulating the carbohydrate content of cookies.

The highest iron content was obtained from macarons with 60% red rice flour and a 3% substitution of moringa flour (F_2). Meanwhile, the lowest iron content was obtained from macarons without red rice flour and moringa flour substitution (F_0). This demonstrates that moringa flour substitution significantly contributes to increasing iron content in macarons, making red rice flour and moringa flour-substituted macarons a potential functional food for preventing anemia. The analysis results show that the iron content in the best macaron formulation (F_2) reached 11.49±0.05 mg per 45 g. This value is higher than the results of a study Setyawati et al (34) which reported iron content in a similar moringa flour based product of 2.108 mg per 100 g. Based on the Indonesian National Agency of Drug and Food Control Regulation No.1 of 2022 (25), food products with a minimum iron content can be claimed as high in iron. Thus, the macarons in this study meet the criteria for iron-rich foods, which have the potential to be developed as functional foods to help prevent anemia. Although there is currently no Indonesian National Standard (SNI) that specifically regulates iron content in baked goods, the results of this study provide a scientific basis for the development of similar iron-rich products.

Nutritional Information

Nutritional value information is compiled based on laboratory test data in grams and milligrams. Nutritional value information is compiled based on the nutritional adequacy figures for adolescent girls aged 16–18 years. The nutritional value information can be seen in **Table 3**. The nutritional value contained in macarons substituted with 60% red rice flour and 3% moringa flour consists of 236 kilocalories, 13.54% total fat, 11.70% protein, 10.59% carbohydrates, and 34.47% iron (35). The nutritional requirements for adolescent girls aged 16–18 years for macronutrients include 2.100 kcal of energy, 65 g of protein, 70 g of fat, and 300 g of carbohydrates. The micronutrient requirement for iron is 15 mg.

Table 3. Nutritional Information of Macaron Substitutes with 60% Red rice flour and 3% Moringa Flour

NUTRITIONAL INFORMATION		
Serving size 45 gram 3 servings per package		
AMOUNT PER SERVING Total Energy	236 kcal	
		% AKG
Total fat	8,80 g	13,54 %
Protein	8,19 g	11,70 %
Total carbohydrates	31,77 g	10,59 %
Iron	5,17 mg	34,47 %
*Percent of Daily Value based on a 2,100 calorie diet. Your energy needs may be higher or lower.		

The macaron product with 60% red rice flour and 3% moringa flour substitution contains 5.17 mg of iron per serving. Meanwhile, the iron requirement for adolescent girls aged 16-18 years is 15 mg/day. Therefore, the consumption of macarons substituted with red rice flour and moringa flour contributes 34.5% of the total daily iron requirement. Based on the Indonesian National Agency of Drug and Food Control Regulation No. 1 of 2022 regarding nutrient claims, it can be concluded that macarons substituted with 60% red rice flour and 3% moringa flour (F_2) fall under the category of iron-rich foods (25)

Level of preference

Figure 3 shows the results of the level of preference for macaron F_0, F_1, dan F_2.

Figure 3. Level of preference for macarons

Description:

F_0 = Macaron without substitution of red rice flour and moringa flour

F_1 = Macaron substituted with 60% red rice flour and 0% moringa flour

F_2 = Macaron substituted with 60% red rice flour and 3% moringa flour

The ANOVA test results for color parameters showed a significant difference with a p-value of 0.001. Further testing showed that macarons without red rice flour and moringa flour substitutions (F_0) were significantly different from macarons substituted with 60% red rice flour and 0% moringa (F_1) and macarons substituted with 60% red rice flour and 3% moringa flour (F_2). The reference product (F_0) has a pinkish color, while the development product (F_1 & F_2) a greenish color is caused by the substitution of moringa flour. Based on hedonic testing, macarons with 60% red rice flour and 3% moringa flour (F_2) produced an average score of 4,15, meaning that the product was liked by the community

The ANOVA test results for the aroma parameter showed no significant difference with a p-value of 0,167. Further tests also showed that there were no significant differences. This means that the use of red rice flour and moringa flour does not affect the final aroma of the product. Based on the hedonic test of macarons with a substitution of 60% red rice flour and 3% moringa (F_2), the average score was 3,98, indicating that the product is liked by the public.

The results of the ANOVA test on taste parameters showed a significant difference with a p-value of 0,001. Further tests showed that macarons without substitution of red rice flour and moringa flour (F_0) were significantly different from macarons substituted with 60% red rice flour and 0% moringa flour (F_1) and macarons substituted with 60% red rice flour and 3% moringa flour (F_2). However, there was no significant difference between macarons substituted with 60% red rice flour and 0% moringa flour (F_1) and macarons substituted with 60% red rice flour and 3% moringa flour (F_2). Based on the hedonic test, macarons with 60% red rice flour and 3% moringa flour (F_2) produced an average score of 4,16, indicating that the product was liked by the community.

The results of the ANOVA test on texture parameters showed significant differences with a p-value of 0,000. Further analysis revealed that macarons without substitution of red rice flour and moringa flour (F_0) were significantly different from macarons substituted with 60% red rice flour and 0% moringa flour (F_1) and macarons substituted with 60% red rice flour and 3% moringa flour (F_2). However, there was no significant difference between macarons with 60% red rice flour and 0% moringa flour (F_1) and macarons with 60% red rice flour and 3% moringa flour (F_2). This means that the substitution of moringa flour does not affect the texture of the product. Based on the hedonic test, macarons with 60% red rice flour and 3% moringa flour produced an average score of 4,29, indicating that the product is liked by the public

The ANOVA test results for the overall parameters showed a significant difference with a p-value of 0,000. Further tests showed that macarons without substitution of red rice flour and moringa flour (F_0) were significantly different from macarons substituted with 60% red rice flour and 0% moringa flour (F_1) and macarons substituted with 60% red rice flour and 3% moringa flour (F_2). However, there was no significant difference between macarons with 60% red rice flour and 0% moringa flour (F_1) and macarons with 60% red rice flour and 3% moringa flour (F_2). This means that substituting 3% moringa flour does not reduce product acceptance. Based on the hedonic test, the substitution of 60% red rice flour and 3% moringa produced an average score of 4,2, indicating that the product was liked by teenagers.

Several previous studies on the use of moringa flour in cookie production have been published and show varying levels of iron content. Azzahra et al (36) reported that adding moringa flour and sorghum flour in cookie production resulted in a cookie with 4.08 mg of iron per 100 grams. Therefore, it was categorized as a source of iron biscuit product. Parwati et al (37) reported that replacing some flour in brownies with moringa flour and mung bean flour resulted in a product containing 2.15 mg of iron per serving. This amount does not meet the minimum requirement of 15% of Recommended Daily Allowance. Therefore, the product cannot be classified as a source of iron. Puspita Dewi et al (38) reported that substituting moringa flour in cookies resulted in 3.15 mg of iron per 100 grams. Therefore, the cookie product was categorized as a source of iron. Meanwhile, Hari Paraswati et al (39) reported that cat tongue cookies substituted with sorghum flour and added moringa leaves contained 2.37 mg of iron per 100 grams. Therefore, the product cannot yet be categorized as an iron source product.

The macarons developed in this study have the advantage of containing iron with 5.17 mg per serving or 11.49 mg per 100 grams, which is higher than in some previous studies. This amount exceeds 30% of the Nutrient Adequacy Rate for adolescent girls aged 16-18 years. Thus, macaron products with red rice flour and moringa flour substitutes qualify as high-iron products. The findings of this study indicate that macarons made with red rice flour and moringa flour have the potential to serve as functional foods that can help meet the iron needs of adolescent girls.

CONCLUSIONS AND RECOMMENDATIONS

The best macaron recipe from this study was obtained by substituting 60% red rice flour and 3% moringa flour (F_2). The substitution of 60% red rice flour and 3% moringa flour in macarons can be categorized as a food high in iron, at 34.47% of the

Recommended Dietary Allowance for iron per 45 g per serving. Teenagers' preference for macarons made with 60% red rice flour and 3% moringa flour (F_2) was favorable in terms of color, aroma, taste, texture, and overall quality. The macaron product with 60% red rice flour and 3% moringa flour substitution can be further improved, particularly to enhance ash content to meet Indonesian National Standard standards, as well as to improve aroma and taste. Additionally, shelf-life testing can be conducted as a basis for developing the product for commercial-scale production.

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