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Acceptability and Iron Content of a Moringa (Moringa oleifera) and Soy-Based Cereal (Keloreal) for Anemia Prevention in Adolescent Girls in Indonesia

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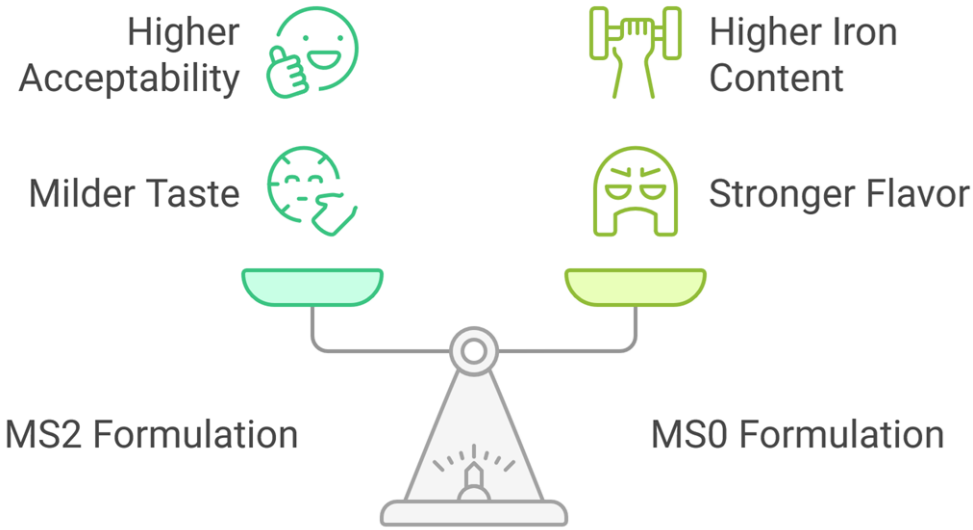
ABSTRACT

The prevalence of anemia in Indonesian adolescent girls reaches 15.5%. Blood supplement tablets are still not accepted by young women. This study was conducted to evaluate the acceptability and iron content of Keloreal. An experimental method was applied, utilizing a hedonic scale to assess attributes of taste, aroma, color, and texture, and the Atomic Absorption Spectrophotometry (AAS) method to determine iron content in the best formula. Data were analyzed using the Kruskal-Wallis test, followed by the Mann-Whitney test. The MS0 formulation received the highest overall hedonic scores. However, among the two treatment formulations, MS2 was more acceptable to the panelists due to its milder bitterness and less prominent moringa flavor, leading to better acceptance compared to MS1. Iron levels measured using the Atomic Absorption Spectrophotometry (AAS) method were 0.0596 mg/g for the MS2 formulation and 0.0756 mg/g for the control (MS0). Despite the lower iron concentration, MS2 is considered a potential alternative snack due to its elevated levels of complementary micronutrients that play a synergistic role in supporting iron metabolism and erythropoiesis.

Key Messages:

- Anemia remains a prevalent nutritional issue among adolescent girls in Indonesia.
- "Keloreal" cereal, formulated with moringa, soy, and maize, offers a nutritious and acceptable snack alternative.
- Among the tested formulations, MS2 demonstrated the highest acceptability among treatment groups due to its milder taste.
- Keloreal has the potential as a functional food to support anemia prevention efforts in adolescents.

GRAPHICAL ABSTRACT



INTRODUCTION

Anemia is a condition in which the number of red blood cells or the concentration of hemoglobin in the cells is lower than normal. Anemia is diagnosed based on hemoglobin levels that are below the threshold of 12 g/dl depending on age, gender, and physiological conditions (1) The main causes of iron anemia among adolescents are the practice of food intake, menstruation, and infectious diseases (2).

Anemia is still a major nutritional problem, especially in vulnerable groups such as adolescent girls and pregnant women. Prevention of anemia requires appropriate interventions through nutrition education, increased knowledge, and fulfillment of iron intake, both from Fe tablets and local food sources. The use of educational media and the development of products based on local ingredients with acceptable organoleptic quality are potential strategies in efforts to prevent sustainable anemia(3–10).

Anemia in adolescent girls is a significant health problem, especially in developing countries. The prevalence of anemia in women aged 15-49 years worldwide reaches 29.9% (1) The prevalence of anemia among adolescent girls aged 15-24 years in Indonesia is 15.5% (11) The prevalence of anemia fluctuated from 18.4% (2013) to 32% (2018) (12) and 15.5% (2023). Anemia in adolescents can impair physical growth, cognitive function, memory, and attention (13) (14)(7). Long-term consequences include pregnancy complications and diminished quality of life, highlighting the need for early intervention.(8).

One promising strategy to prevent anemia is through the consumption of iron-rich foods. Moringa leaf powder contains protein (23.78 g), calcium (2003 mg), and iron (28.2 mg) per 100 grams. Besides its nutritional value, moringa also has functional properties such as anticancer, antidiabetic, and antimicrobial effects. Previous studies have shown that moringa-enriched products can increase hemoglobin levels in adolescent girls. In the study of moringa chocolate, it was found that moringa chocolate affects the hemoglobin levels of adolescent girls (9). Studies on therapeutic feeding in children with anemia and severe malnutrition have shown that ready-to-eat therapeutic foods made from soy, corn, and dairy-free sorghum (FSMS-RUTF) are more effective in treating anemia and increasing iron stores than those made from pea-milk formulations (PM-RUTF), without increasing the risk of iron overload or intestinal inflammation (10). Corn- and soy-based ready-to-use therapeutic foods (RUTFs) have been shown to be effective in improving the nutritional status of malnourished children in several previous studies. Therefore, the selection of cornstarch and soybeans as the basic ingredients in Keloreal products is based on their effectiveness and proven nutritional value. A study on soy-based ice cream fortified with moringa leaf flour found that it could serve as a healthy snack alternative for adolescents, as it helps increase iron intake (11).

Anemia remains a critical public health concern, particularly among adolescent girls in Indonesia, where inadequate iron intake is a major contributing factor. Addressing this issue through food-based interventions offers a sustainable and culturally appropriate solution. Functional food products, such as

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cereals enriched with moringa and soy, offer a promising solution. This study introduces 'Keloreal,' a cereal made from moringa, soy, and maize, developed as a practical and nutritious morning snack using locally sourced, affordable, and widely available ingredients. In addition to its functional benefits, Keloreal is intended to be acceptable in terms of taste and sensory characteristics. This study was conducted to evaluate the acceptability and iron content of Keloreal cereal products, thereby assessing its potential as a preventive strategy for anemia among adolescent girls.

METHODS

This study employed an experimental design with a quantitative approach. Three formulations were tested: MS0 (control), MS1, and MS2, each with varying proportions of cornstarch, soy, moringa powder, egg yolk, and skimmed milk. The research was conducted from December 2024 to May 2025. The study took place in two locations: the Taste Test Laboratory of the Department of Nutrition, Ministry of Health, Surabaya, for the acceptability test, and the Energy and Environment Laboratory at ITS Surabaya for iron level analysis. The acceptability test involved 30 untrained panelists who evaluated the product's taste, color, aroma, and texture. Prior to participation, all panelists were provided with detailed information about the study's objectives, procedures, risks, and benefits, and were asked to complete a consent form. The samples tested consisted of three Keloreal formulations prepared according to specific recipes. Following the acceptability test, one treatment formulation with the highest score and one control formulation were selected for iron content analysis. Data collection was carried out through two types of tests. The acceptance test uses a hedonic scale consisting of five levels of liking, ranging from very dislike to very like. Each panelist rated each Keloreal sample based on taste, color, aroma, and texture. Iron levels were analyzed using the Atomic Absorption Spectrophotometry (AAS) method, which involves weighing, digesting, and measuring the samples at specific wavelengths for iron. Sample preparation involves dissolution using concentrated HNO_3 and HCl, and the iron content is expressed in mg/g.

The data obtained were analyzed using SPSS software. The Kruskal–Wallis test was employed to assess differences in acceptability among the formulations, with a significance level set at $\alpha < 0.05$. If significant differences were found, the analysis was followed by the Mann–Whitney test to identify differences between formulation pair. Meanwhile, the results of iron levels were analyzed descriptively and compared with the Nutritional Adequacy Rate (AKG) of adolescent girls aged 18 years. Keloreal products are categorized as a source of iron if the iron content per serving meets the criteria of the POM Agency, which is more than 7.5% of the Nutritional Adequacy Rate (AKG).

RESULTS

Keloreal is a cereal enriched with ground moringa leaves and soybeans. The ingredients for making Keloreal consist of cornstarch and soybeans. During the production process, ground moringa leaves, egg yolk, baking powder, vanilla powder, mineral water, Diabetasol sugar, skimmed milk, and full-cream milk were added. The MS0 formula served as the control and consisted of wheat flour, skimmed milk, full-cream milk, egg yolk, baking powder, vanilla powder, mineral water, and Diabetasol sugar. In contrast, the MS1 and MS2 treatment formulas included additional ingredients such as ground moringa leaves and soybeans. These compositional differences were aimed at assessing variations in the characteristics of each formulation.

Table 1. Characteristics of Each Formula

Indicator	Formula		
	MS0	MS1(20:30:5)	MS2 (27:25:3)
Color	Light brown with a yellowish hue	Dark green brownish	Light green
Aroma	Aroma of eggs and milk	Strong moringa aroma	Slight moringa aroma
Taste	Sweet, savory from egg milk	Sweet, with a hint of bitterness	Sweet, with a slight hint of bitterness
Texture	Dry but easily crumbled	Crips but slightly hard	Crisp

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MS0: Wheat flour, egg yolk, and skimmed milk (55:40:20)
MS1: Cornstarch, Soybeans, Moringa Powder, Egg Yolk, and Skimmed Milk (20:30:5:40:20)
MS2: Cornstarch, Soybeans, Moringa Powder, Egg Yolks, and Skimmed Milk (27:25:3:40:20)

Acceptance Test

The results of the acceptability test were used to assess the panelists' level of acceptance for each formulation, based on the indicators of color, aroma, taste, and texture of Keloreal.

Table 2. Hedonic Test Value Against Keloreal Formulation

Indicator	Formula			Kruskal Wallis
	MS0	MSI 1	MS2	*Test Value*
Color	4.16	3.06	3.43	0.000
Aroma	4.23	2.93	3.7	0.000
Taste	4.53	2.4	3.9	0.000
Texture	4.16	3.3	3.66	0.000
Average	**4.27**	**2.92**	**3.67**	

Information: 1= Strongly Dislike, 2= Dislike, 3= Neutral, 4= Like, 5= Strongly Like

Based on the results of the hedonic test presented in the table, the MS0 formulation received the highest scores across all sensory attributes color (4.16), aroma (4.23), taste (4.53), and texture (4.16) with an overall average score of 4.27. This indicates that MS0 was the most preferred formulation by the panelists. Among the two treatment formulations, MS2 was more acceptable than MS1, with a higher overall average score (3.67 vs. 2.92), particularly in taste (3.9) and aroma (3.7). This suggests that the moringa flavor in MS2 was less pronounced, making it more favorable than MS1. The Kruskal–Wallis test was used to determine whether there were significant differences in the color, aroma, taste, and texture attributes of Keloreal. Atomic Absorption Spectrophotometry (AAS) analysis was performed in duplicate for each selected formulation. The results of the Kruskal-Wallis test showed a very small p-value (0.000) on all indicators (color, aroma, taste, and texture), indicating a significant difference between the formulations tested. The p < value of 0.05 indicated that the differences between the formulation groups in each of these indicators do not occur by chance, so it can be concluded that each formulation exerts a different influence on the acceptance of panelists based on color, aroma, taste, and texture.

Table. 3 Mann-Whitney *Test Results* on the Acceptability of Keloreal Formulations

Indicator	Mann-Whitney's *Test Score*		
	MS0:MS1	MS0:MS2	MS1:MS2
Color	0.000	0.001	0.062
Aroma	0.000	0.007	0.000
Taste	0.000	0.019	0.066
Texture	0.000	0.004	0.000

Based on the results of the Mann–Whitney test (tabel 3), significant differences were found in most sensory attributes between formulations. In the comparisons between MS0 (control) and MS1 (treatment), as well as between MS0 and MS2, the p-values for color, aroma, taste, and texture were all below 0.05, indicating statistically significant differences. However, in the comparison between MS1 and MS2, the p-values for color (p = 0.062) and taste (p = 0.066) were greater than 0.05, indicating no significant differences in these two attributes. Meanwhile, aroma (p = 0.000) and texture (p = 0.000) still showed significant differences. These results suggest that the tested formulations underwent significant changes in most sensory characteristics, except for color and taste, in the comparison between MS1 and MS2.

Iron Levels Test

The results of the iron level test were used to determine whether there was a difference in iron content between the two Keloreal formulations. Atomic Absorption Spectrophotometry (AAS) analysis was performed in duplicate for each selected formulation.

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Table 4. Iron Content Results of Control and Best Treatment Formulations

Formula	Fe (mg/g)
MS0	0.0756
MS2	0.0596

The results of the iron content test showed a difference between the two Keloreal formulations. The MS0 formulation contained 0.0756 mg/g of iron, while the MS2 formulation contained 0.0596 mg/g (Tale 4).

Table 5 Nutritional Content of the Best Control Formula and Treatment Formula

Nutritional Content	MS0	MS2
Energy (kcal)	202.1	206.61
Protein (g)	10.58	11.89
Fat (g)	6.94	8.24
Carbohydrates (g)	23.37	20.59
Fiber (g)	0.49	0.94
Iron (mg)	1.15	1.9
Vit. A (µg)	156.2	164.7
Vit. C (mg)	2.16	5.18
Vit. B1 (mg)	0.44	0.67
Vit. B2 (mg)	0.12	0.21
Niasin (mg)	1.5	2.4
Potassium (mg)	349.47	396.48
Calcium (mg)	239.31	286.28
Magnesium (mg)	30.4	35.79
Phosphorus (mg)	237.65	265.77
Zinc (mg)	1.09	1.07
Copper (mg)	0.06	0.07

Based on calculations using *Tabel Komposisi Pangan Indonesia* (TKPI), the MS2 formulation has a higher nutritional content than MS0, particularly in iron (1.90 mg vs. 1.15 mg), vitamin C (5.18 mg vs. 2.16 mg), protein, fiber, and several other micronutrients. This increase is attributed to the addition of nutrient-rich ingredients such as moringa and egg yolk. The combination of iron and vitamin C in MS2 supports its potential as a functional food for anemia prevention. However, laboratory test results show an opposite trend, where the measured iron content is lower than the calculated value. Therefore, further analysis is needed to investigate iron bioavailability and potential losses during the production process.

Table 6. Percentage of AKG Fulfillment in the Best Treatment Formulation

Nutritional Content	MS2 Content	10% AKG Fulfillment	MS1 Content	10% AKG Fulfillment
Energy (kcal)	206.61	98.40%	205.5	97.90%
Protein (g)	11.89	182.90%	12.6	193.80%
Fat (g)	8.24	117.70%	8.6	122.90%
Carbohydrates (g)	20.59	74.90%	19.2	64.00%
Fiber (g)	0.94	37.60%	2.4	82.80%
Iron (mg)	1.9	126.70%	2.2	146.70%
Vit. A (µg)	164.7	274.50%	166.5	277.50%
Vit. C (mg)	5.18	69.10%	5.9	78.70%
Vit. B1 (mg)	0.21	190.90%	0.2	181.80%
Vit. B2 (mg)	0.67	670%	0.8	800%
Niasin (mg)	2.4	171.40%	0.7	50%
Potassium (mg)	396.48	79.30%	414.1	82.80%
Calcium (mg)	286.28	238.60%	606.7	505.60%
Magnesium (mg)	35.79	155.60%	39	169.60%
Phosphorus (mg)	265.77	212.60%	275.1	220.10%
Zinc (mg)	1.07	118.90%	1.1	122.20%
Copper (mg)	0.07	78.70%	0.1	112.40%

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DISCUSSION

Based on the results of the hedonic test of 30 untrained panelists, significant differences were found in all sensory attributes (color, aroma, taste, and texture) between the formulations of Keloreal MS0 (control), MS1, and MS2. A score of at least 3 on the hedonic test is considered a condition for the product to be well received, as it represents a neutral to positive level of preference. The MS0 formulation obtained the highest score on all parameters, with an overall average of 4.27. This suggests that MS0 was preferred due to its sweet and savory taste derived from milk and egg, as well as its familiar aroma, which resembled that of commercial products (12). In contrast, MS1 received the lowest scores due to its less appealing color, strong moringa aroma, unbalanced bitter-sweet taste, and coarse texture. Among the two treatment formulations, MS2 was rated the highest, with an average score of 3.67. MS2 was considered the better treatment formulation because it had more balanced flavor and color characteristics compared to MS1.

The results of the Kruskal-Wallis test showed a very small p-value (0.000) on all indicators (color, aroma, taste, and texture), indicating a significant difference between the formulations tested. In contrast, MS1 received the lowest scores due to its less appealing color, strong moringa aroma, unbalanced bitter-sweet taste, and coarse texture. Among the two treatment formulations, MS2 received the highest rating, with an average score of 3.67. It was considered the better treatment formulation because of its more balanced flavor and color characteristics compared to MS1.

The Mann–Whitney test showed significant differences in color between MS0–MS1 ($p = 0.000$) and MS0–MS2 ($p = 0.001$), but not between MS1–MS2 ($p = 0.062$), indicating that the color difference between the two treatment formulations was not perceived as significant by the panelists. For aroma, all comparisons showed significant differences ($p < 0.05$), suggesting that the intensity of moringa aroma varied among formulations, with MS1 having the strongest aroma and MS2 being milder and more acceptable. In terms of taste, significant differences were found between MS0–MS1 ($p = 0.000$) and MS0–MS2 ($p = 0.019$), but not between MS1–MS2 ($p = 0.066$), indicating that MS2 had a more balanced flavor compared to the bitterness found in MS1. Regarding texture, all comparisons were significant ($p < 0.05$), with MS0 being the crispiest, MS1 having a harder texture, and MS2 showing an intermediate texture that was preferred over MS1.Laboratory tests of iron content using the Atomic Absorption Spectrophotometry (AAS) method revealed that MS0 had a higher iron concentration (0.0756 mg/g) compared to MS2 (0.0596 mg/g), contrary to prior estimates based on NutriSurvey calculations.

Based on the nutritional composition analysis using TKPI, the MS2 formulation, which contains moringa leaves and soybeans, showed higher macronutrient and micronutrient content compared to MS0. The energy of MS2 reaches 206.61 kcal and protein 11.89 g, higher than MS0 (202.10 kcal and 10.58 g). Micronutrients such as vitamins A, B1, B2, niacin, vitamin C, calcium, magnesium, and phosphorus are increased, supporting the hematopoietic system and cell metabolism (11). However, there was a discrepancy between the estimated iron content per 30 g of formulation based on ingredient composition (MS2: 1.90 mg; MS0: 1.15 mg) with AAS test results (MS2: 1.7 mg; MS0: 2.2 mg). The lower iron content detected in MS2 may be attributed to the replacement of fortified wheat flour with cornstarch, as well as the presence of phytic acid and polyphenols in moringa and soybeans, which inhibit iron absorption by forming complexes that may render iron undetectable by the AAS method. Phytic acid, a known antioxidant and antinutrient, binds to proteins and minerals, forming insoluble complexes that reduce the solubility and bioavailability of nutrients (21) (14). Phytate specifically binds to iron, making it difficult to absorb, while calcium and polyphenols also contribute to decreased iron absorption. In contrast, vitamin C has been shown to enhance iron absorption (15). To improve the bioavailability of iron in Keloreal, future formulations should consider the addition of vitamin C-rich ingredients, high-quality protein sources, and prebiotics that support mineral absorption To improve the bioavailability of iron in Keloreal, future formulations should consider the addition of vitamin C-rich ingredients, high-quality protein sources, and prebiotics that support mineral absorption (24) (17). While the inclusion of moringa and soybeans represents a valuable nutritional innovation, a balanced formulation is essential to maximize the iron benefits. Overall, although MS0 received higher sensory preference, MS2 demonstrates greater nutritional potential and can be further developed as a functional food product to help prevent anemia in adolescent girls.

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The MS2 cereal still demonstrates potential as a nutritional intervention for anemia prevention, due to its micronutrient content that supports iron metabolism and red blood cell formation. The content of vitamin C MS2 is 5.18 mg, supporting the physiological absorption of iron (26) Vitamin A of 164.7 µg also helps mobilize iron from the body's reserves (27) Vitamin B2 (riboflavin) is the dominant nutrient in MS2 (0.67 mg; 670.6% AKG), which supports energy metabolism, cell regeneration, and puberty growth (28) The content of vitamins B1 (0.21 mg) and niacin (2.4 mg) supports nerve function and energy (29) Minerals such as calcium (286.28 mg; 118.9% AKG) are beneficial for bone and hemoglobin formation (30)), magnesium (35.79 mg; 155.6% AKG) support nerve function and reduce PMS symptoms (31)and zinc (1.07 mg; 118.9% AKG) are important for DNA synthesis, immune function, as well as iron metabolism (32) This combination makes MS2 a functional food that supports the metabolic health, hematological, and growth of adolescent girls.

The AAS analysis showed that MS2 had a lower iron content than MS0; however, nutritional assessment based on TKPI indicated that MS2 contained higher levels of energy (206.61 kcal) and protein (11.89 g). Furthermore, MS2 demonstrated superior concentrations of key micronutrients such as vitamins A, B1, B2, niacin, vitamin C, calcium, magnesium, and phosphorus, all of which contribute to iron metabolism and red blood cell formation. The presence of vitamin C (5.18 mg) supports iron absorption, while vitamin A (164.7 µg) aids in mobilizing stored iron. The high vitamin B2 content (0.67 mg) also plays a significant role in energy metabolism and adolescent growth. Given its nutrient composition, the MS2 formulation remains a promising candidate as a functional food for the prevention of anemia in adolescent girls.

The iron test was only performed twice, not according to Federer's formula standards due to time and cost limitations. Therefore, the results need to be interpreted carefully and become the basis for further research improvements. Based on the AKG, the iron requirement for adolescent girl snacks is 1.5 mg. With a content of 0.0596 mg of iron per gram, 1 sachet (30 g) of Keloreal contains 1.7 mg of iron. This means that one sachet of Keloreal is enough to meet the daily iron needs of a one-meal snack for young women, which is 10% of the AKG. According to BPOM, MS2 is a product that can be said to contain iron because it contains 11.3% mg of iron (33)

Based on regulation of the Head of BPOM No. 9 of 2016, the Nutrition Label Reference for iron is 22 mg per day, which serves as an official benchmark in assessing the nutritional contribution of processed food products in the context of labeling. Referring to BPOM Regulation No. 1 of 2022, a solid product can be claimed as a "source of iron" if it contains at least 15% of ALG per 100 grams, which is equivalent to 3.3 mg of iron, and can be claimed to be "high in iron" if it contains 6.6 mg or more per 100 grams. The MS2 formula contains 0.0596 mg/g or equivalent to 5.96 mg/100 g, making it eligible to be claimed as a "source of iron" (Table 6). Therefore, the iron profile of the MS2 formula is explicitly in accordance with the provisions of the regulations in submitting nutritional claims, and can be considered to support health claims related to the prevention of anemia in the context of functional foods (34,35).

Strengthening the findings related to iron levels in Keloreal products requires further research that examines the effects of processing on nutrient retention, particularly iron. The heating used in the manufacture of cereals can cause iron loss or change its chemical form, so it is not detected through the AAS method. Therefore, iron levels measurements before and after processing need to be carried out to evaluate the extent to which the process affects the availability of nutrients. In addition, considering that phytic acid has been identified as an antinutrient that has the potential to inhibit iron absorption, the measurement of antinutrient levels such as phytic acid in raw materials and final products is important. With this quantitative data, a direct correlation analysis can be carried out between antinutrient levels and iron bioavailability, so that discussions that have been qualitative can be improved into a more robust and scientifically relevant quantitative approach.

Cost analysis of the MS2 formulation showed that the total cost of raw materials amounted to IDR 15,315, with the highest contributions from full cream milk powder (IDR 6,060) and Diabetasol sugar (IDR 4,480), while other ingredients such as cornstarch and moringa leaves contributed smaller portions. After including additional production costs—such as LPG, packaging, and triangle plastic—amounting to IDR 3,800, the total production cost reached IDR 19,115 for three packages. Therefore, the production cost per

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package was IDR 6,372. By adding a 10% profit margin, the selling price per package was set at IDR 7,009. This calculation demonstrates that Keloreal is not only nutritionally beneficial but also economically feasible to be marketed as a functional snack for adolescent girls.

CONCLUSION

The average acceptability of MS0:4.27, MS1:2.92, and MS2:3.67. MS0 formulation has the best acceptability (4.27), followed by MS2 (3.67) as the treatment formula with the best acceptability. The highest iron level was found at MS0 (0.0756 mg/g), while MS2 was 0.0596 mg/g. Despite this, MS2 retains significant potential as a functional snack for anemia prevention, particularly given its overall nutritional profile. Future research should focus on exploring broader variations in moringa and soy concentrations, as well as incorporating ingredients rich in vitamin C, prebiotics, and protein to optimize iron bioavailability and ensure more accurate AAS readings. In addition to adding vitamin C-rich ingredients, the development of Keloreal can consider fermentation or germination techniques in soybeans and moringa. This method has been shown to lower phytic acid and potentially increase iron bioavailability. Institutions are encouraged to provide adequate laboratory facilities, foster industrial collaboration, and implement policies that promote the utilization of local food resources for such interventions.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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