



## Development of multigrain snack bar with tempeh flour and spirulina for adolescent nutrition

### *Pengembangan multigrain snack bar dengan tepung tempe dan spirulina untuk gizi remaja*

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## Abstract

The prevalence of adolescent malnutrition in Indonesia is still high, namely stunting (23,7-24,1%), overweight/obesity (12,1-16,2%), and anemia (16,2%). One contributing factor is the consumption of unhealthy foods. This study aimed to develop a multigrain snack bar by adding tempeh flour and Spirulina, which provide protein, iron, and fiber, to prevent malnutrition. This study was conducted from March to May 2025 using a completely randomized design with tempeh flour and spirulina powder proportions of 95:5 (F1), 90:10 (F2), and 85:15 (F3). The product formulation was performed at the Nutrition Laboratory of Universitas Muhammadiyah Cirebon, Cirebon. The analysis included organoleptic (30 panelists), nutritional content, formula selection, and nutritional contribution analyses. Data were analyzed using ANOVA with Duncan's test. There were significant differences in color, aroma, taste, overall, ash, fat, protein, carbohydrate, and iron content among the formulations ( $p < 0.05$ ). F1 was the optimal formulation, with 17,63% protein, 3,24 mg/100 g iron, and 3,86% fiber. One serving (20 g) contributed 4-5% of the energy requirement for adolescents (13-18 years). In conclusion, F1 was the most preferred and provided essential nutrients to meet the needs of adolescents. This study is novel in that it develops a product from tempeh and Spirulina as a potential innovative solution to address nutritional problems in adolescents.

**Keywords:** Adolescent malnutrition, multigrain snack bar, spirulina, tempeh flour, functional food.

## Abstrak

Prevalensi malnutrisi remaja di Indonesia masih tinggi yaitu stunting (23.7-24.1%), overweight/obesitas (12.1-16.2%), dan anemia (16.2%). Salah satu faktor penyebabnya adalah konsumsi camilan yang tidak sehat. Penelitian ini bertujuan untuk mengembangkan multigrain snack bar dengan menambahkan tepung tempe dan spirulina sebagai camilan bergizi yang mengandung protein, zat besi, dan serat untuk mencegah malnutrisi. Penelitian ini dilakukan dari Maret hingga Mei 2025 dengan rancangan acak lengkap, menggunakan proporsi tepung tempe dan bubuk spirulina sebesar 95:5 (F1), 90:10 (F2), dan 85:15 (F3). Formulasi produk dilakukan di Laboratorium Gizi Universitas Muhammadiyah Cirebon, Cirebon. Analisis meliputi organoleptik (30 panelis), kandungan gizi, pemilihan formula, dan kontribusi gizi. Data dianalisis menggunakan ANOVA dengan uji Duncan. Terdapat perbedaan yang signifikan pada warna, aroma, rasa, keseluruhan, abu, lemak, protein, karbohidrat, dan zat besi di antara formulasi ( $p < 0.05$ ). F1 adalah formulasi terbaik dengan 17.63% protein, 3.24 mg/100 g zat besi, dan 3.86% serat. Satu sajian (20 g) berkontribusi 4-5% kecukupan energi remaja (13-18 tahun). Kesimpulannya, F1 merupakan yang paling disukai dan menyediakan zat gizi esensial untuk mendukung kebutuhan gizi remaja. Penelitian ini

memberikan kebaruan dengan mengembangkan produk berbahan tepung tempe dan spirulina sebagai solusi inovatif yang potensial dalam penanganan masalah gizi pada remaja.

**Kata Kunci:** Malnutrisi remaja, multigrain snack bars, spirulina, tepung tempe, pangan fungsional.

## Introduction

Malnutrition among Indonesian adolescents continues to be a significant issue. The Indonesian Health Survey in 2023 reported that among those aged 13-15 years, 24.1% were stunted, 7.6% thin, and 16.2% overweight/obese. In the 16-18 age group, 23.7% were stunted, 8.3% thin, and 12.1% overweight/obese. Furthermore, anemia affects 16.2% of the population, with 31.8% of cases occurring in children and adolescents (Kementerian Kesehatan, 2023). These conditions underscore the need to address adolescent malnutrition to achieve the 2030 Sustainable Development Goals (SDGs) of eradicating all forms of malnutrition (Indriyastuti & Kartono, 2022; Komarulzaman et al., 2023).

Adolescent malnutrition is influenced by various factors, including snacking habits (Hidayanti et al., 2025; Rachmi et al., 2021). The types of snacks commonly consumed by adolescents include sugar-sweetened beverages (SSBs), confectionery and sugary snacks, and ultra-processed foods (Casey et al., 2021; Islam et al., 2022; Wang et al., 2022). The Indonesia Basic Health Research 2018 showed that 61.3% of individuals aged  $\geq 3$  years consume SSBs daily. Other studies have reported that 90% of adolescents frequently consume SSBs and 51.6% consume ultra-processed foods excessively (Ginting et al., 2024; Sari et al., 2022). These foods are typically high in energy, sugar, fat, and sodium but low in fiber and essential micronutrients, thereby contributing to nutrient imbalances (Al-Jawaldeh et al., 2020; Pries et al., 2019). Therefore, developing healthier snack alternatives is a practical approach to address adolescent malnutrition.

The nutritional components that warrant attention in snack products designed for adolescents include protein, iron, and fiber intake. This effort aims to address the deficiencies in protein, iron, and fiber that are prevalent among adolescents (Cohen & Powers, 2024; Rambe et al., 2021). A study found that adolescents in Depok, Indonesia, had insufficient

protein (59.7%) and iron (98.6%) intakes (Khoirunnisa et al., 2021). Protein and iron deficiencies can impair growth, reduce immune function, and increase the risk of anemia. Fiber consumption in Indonesian adolescents also remains inadequate, with an average intake of only 3.9–4.9 g/day, far below the recommended 27–37 g/day (Hidayanti et al., 2023; Musfira & Hadju, 2024). Insufficient fiber intake increases the risk of obesity and chronic diseases. Tempeh and spirulina are ingredients with the potential to be developed into snack products that provide protein, iron, and fiber.

Tempeh is a fermented soybean food made with the fungus *Rhizopus oligosporus*. Tempeh can be processed into tempeh flour. Tempeh flour was prepared by grinding dried tempeh into powder (Romulo & Surya, 2021). Tempeh flour has a high protein content, making it an ideal basis for protein-rich products. The protein content in pure soybean tempeh is 20.8%, whereas that in the flour form is 46% (Kementerian Kesehatan Republik Indonesia, 2020). In addition, tempeh is a source of iron and has relatively high fiber content (Kementerian Kesehatan Republik Indonesia, 2020).

Spirulina is a microalga approved for consumption as food or as a supplement (Anvar & Nowruzzi, 2021). Spirulina has a high protein and mineral content, specifically protein ranging from 56% to 62% and minerals from 3% to 7% (Podgórska-Kryszczuk, 2024; Priyanka et al., 2023). This makes spirulina a potential solution for overcoming malnutrition in adolescents. Studies have shown that spirulina supplementation can increase body weight, height, hemoglobin levels, and serum ferritin levels in malnourished children (Barennes et al., 2022; Lacurezeanu & Vodnar, 2025).

Tempeh flour and spirulina can be combined to produce various processed food products, including multigrain snack bars. Snack bars are widely recognized as a well-accepted and practical food format for nutritional interventions in adolescents (Herdianto et al., 2025; Sandhya & Kanniammal, 2024). The addition of tempeh flour and Spirulina to snack

bars is expected to make this product a source of protein, Fe, and fiber. The addition of tempeh flour and Spirulina to the multigrain snack bar represented the main novelty of this study. To date, snack bar studies have used tempeh flour or spirulina separately; no study has combined the two in a multigrain snack bar formulation for adolescents (Dewanti et al., 2024; Doiphode & Mane, 2021; Mawarno & Putri, 2022). This study lays the foundation for future research and innovation in the development of adolescent-focused multigrain snack bars made with tempeh flour and Spirulina.

## Methods

### Study design

This study was a laboratory experiment with a completely randomized design using three different formulas. Each formula was analyzed in duplicate. The study will be conducted between March and May 2025. The snack bar was prepared at the Dietetic and Culinary Laboratory, and the organoleptic test was performed at the Organoleptic Laboratory of the Nutrition Department, Universitas Muhammadiyah Cirebon, Cirebon. Proximate content (moisture, ash, protein, fat, and carbohydrate), iron content, and crude fiber were determined at the Saraswati Indo Genetech (SIG) Laboratory, Bogor. This study underwent an Ethics Test by the Mahardika Institute of Technology Ethics Commission (KEP Mahardika). This study was conducted in accordance with the ethical principles of the Ethics Committee (number: 072/KEPK). ITEKESMA/IV/2025.

### Multigrain Snack Bar Preparation

Table 1 presents the formulation of a multigrain snack bar with the addition of tempeh flour and spirulina powder in different proportions (95:5, 90:10, and 85:15, by weight). The materials used were commercial tempeh flour, commercial Spirulina powder, rolled oats, sunflower seeds, pumpkin seeds, puffed rice, dates, honey, raisins, brown sugar, corn sugar, and peanut butter.

The multigrain snack bar was prepared by mixing dry and wet ingredients to form a homogeneous dough, which was further shaped and baked into a solid structure. The dry ingredients (tempeh flour, sunflower seeds, pumpkin seeds, and oats) were combined and roasted over low heat for 5 min. Spirulina

powder and raisins were then added to the dry mixture of flour. The wet ingredients (honey, dates, brown sugar, corn sugar, and peanut butter) were stirred moderately until homogeneous. The wet mixture was then combined with the dry mixture until it was uniformly blended. The mixture was subsequently shaped into a bar mold and baked in three stages. Preliminary baking was performed at 90 °C for 18 min. The next baking step was performed at 150 °C for 8 min. The final baking was performed at 90 °C for 5 min. The cooked snack bars were refrigerated for 10 min to obtain a solid texture.

**Table 1.** Formulation (g) of multigrain snack bar with different addition of tempeh flour and spirulina (95:5, 90:10, and 85:15 by weight)

Ingredient	F1 (95:5)	F2 (90:10)	F3 (85:15)
Tempeh flour	95	90	85
Spirulina powder	5	10	15
Rolled oat	95	95	95
Puffed rice	70	70	70
Sunflower seed	60	60	60
Pumpkin seed	70	70	70
Dates	95	95	95
Honey	95	95	95
Raisins	50	50	50
Brown sugar	70	70	70
Corn sugar	13	13	13
Peanut butter	55	55	55

### Organoleptic Test

An organoleptic test was performed using a hedonic sensory test, which involved 30 semi-trained panelists selected through purposive sampling, including male and female panelists. The semi-trained panelists participating in this sensory evaluation received a brief hour-long training on sensory evaluation methods. Sensory evaluation was conducted in a well-ventilated room that provided sufficient lighting and was free from odor. Each panelist received drinking water during the assessment to neutralize their mouths before testing the product samples. The panelists met several criteria, including the absence of allergies to spirulina, tempeh, and nuts, good health status, no olfactory impairments, and no color vision deficiencies. The panelists provided informed consent before participating in this test.

Multigrain snack bars were served and arranged on plastic plates, each labelled with a randomly assigned three-digit code. The multigrain snack bars were evaluated in terms of acceptability based on their color, aroma, taste, texture, and overall acceptance using a 9-point hedonic scale. The scale extended from "like very much" to "dislike very much," aligning with the maximum and minimum scores of "9" and "1," respectively.

### **Analysis of Nutritional Content**

The analysis comprised proximate (moisture, ash, fat, protein, carbohydrates, and energy), iron, and crude fiber. The moisture content was determined using the oven-drying method (SNI 8217-2015). Ash content was assessed using the incineration of the sample (SNI 01-2891-1992). Lipid content was conducted using the Soxhlet extraction method (SNI 01-2891-1992).

The protein content was assessed by titrimetric analysis using the Kjeldahl method (18-8-31/MU/SMM-SIG). Carbohydrates (By Difference) and energy were determined using a calculation method. The iron (Fe) content was determined by microwave digestion using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (18-13-1/MU/SMM-SIG). The crude fiber content was measured using the gravimetric method.

### **Analysis of Selected Formula and Nutrient Contribution to Adolescent Needs.**

The formula selected in this study was analyzed using the exponential comparison method. Two aspects were considered in the analysis: the results of the organoleptic test and the nutritional content. The weight of each parameter was determined by its relevance to the objective of developing this product as an alternative snack for adolescents that provides protein, iron, and fiber. The weight values for each parameter were as follows: 5% color, 10% aroma, 15% taste, 10% texture, 5% moisture, 5% ash, 5% fat, 15% protein, 5% carbohydrate, 15% iron, and 10% fiber. The selected formulation was the one with the lowest total value from the ranking calculation.

The nutrient contribution of the selected formula to adolescent needs was calculated based on the Nutritional Label Guidelines (NLG) and the Recommended Dietary Allowances (RDA). The NLG percentage was determined

using the reference table for the general population provided by the Indonesian Food and Drug Authority (Badan Pengawas Obat dan Makanan, 2016). The RDA percentage value was calculated based on the reference table for adolescents aged 13-18 years, applicable to both boys and girls, as provided by the Indonesian Ministry of Health (Kementerian Kesehatan, 2019).

### **Statistical Analysis**

Data were analyzed using Microsoft Excel and SPSS 15 for Windows. The organoleptic properties and nutritional content were analyzed using One-way ANOVA to evaluate the effects of different proportions of tempeh flour and spirulina, followed by Duncan's test to determine the differences among the formulas. Significant differences in the means were identified at *p* of less than 0.05.

The nutrient contribution to the adolescent's needs was analyzed descriptively because the data were not direct measurements but calculations.

## **Result and Discussion**

### **Organoleptic evaluation**

The organoleptic analysis performed in this study was a hedonic test. This test aimed to evaluate the preferences of the panelists regarding the product samples. Table 2 presents the findings of the test analysis. The results showed significant differences in color, aroma, taste, and overall acceptance among the formulas. However, the texture attributes did not differ significantly among the three formulas.

Hedonic testing of color attributes showed that the panelists preferred F1 snack bars among the other formulas. Statistical analysis indicated that the color preference of F1 was significantly different from that of F2 and F3. F1 was in the range of slightly to moderately for the color attribute. F1 produced a predominant brown color with a slight greenish tint. The results also showed that the increased spirulina powder content corresponded with a decreased color preference among panelists. This preference was probably due to the green coloration of the sample, which was less attractive to the panelists. Chlorophylls are bioactive substances prevalent in Spirulina. This phytochemical imparts a vibrant green color

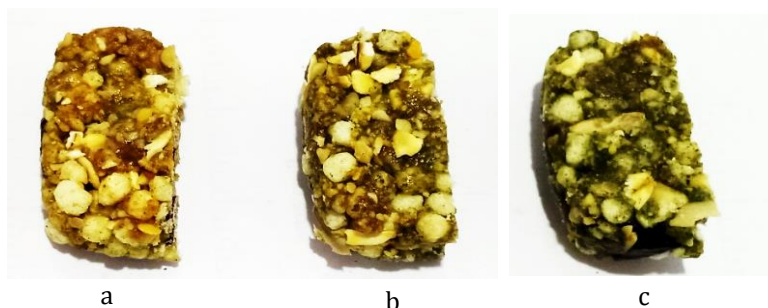
(Bortolini et al., 2022). Several studies have indicated that an increased percentage of Spirulina corresponds to a more intense green coloration of noodles and milk products (de Oliveira et al., 2021; Erysyah et al., 2022). Chlorophylls represent one of the most

substantial limitations of product use. Greenish colors may adversely affect the overall appearance of the products. Color significantly influences the sensory perception. As the first attribute observed, it may affect consumer preferences (Bortolini et al., 2022).

**Table 2.** Results of the hedonic sensory test of multigrain snack bar

Sensory Attributes	Formula			p-value
	F1	F2	F3	
Color	6.80±1.31a	5.71±1.95b	5.58±2.67b	0.045
Aroma	6.47±1.56a	5.37±1.75b	5.06±2.03b	0.007
Taste	7.10±1.32a	5.46±2.28b	5.16±2.73b	0.002
Texture	6.77±1.50a	6.11±1.48a	6.29±1.85a	0.269
Overall	6.79±1.95a	5.69±1.32b	5.57±1.81b	0.002

*a,b,c Means of the same row with differing superscripts are significantly different ( $P < 0,05$ ), F1=95:5, F2=90:10, F3=85:15*



**Figure 1.** Multigrain snack bar products (F1 (a), F2 (b), and F3 (c))

Regarding aroma, F1 was the most preferred formula by the panelists. The difference test results indicated that F1 exhibited a significant difference compared to F2 and F3. F1 was in the range of slightly to moderately for the aroma attribute. F1 produced a more dominant tempeh aroma than the other formulas. However, F1 also produced a slightly fishy and grassy aroma owing to the presence of spirulina. The results also indicated that an increase in spirulina powder percentage in the formula corresponded to a decrease in aroma preference among panelists. Another finding also showed the same results. Erysyah et al., (2022) reported that an increase in spirulina concentration led to a decrease in the aroma preference of the dry noodle product. The acceptance of spirulina by panelists may be limited by its fishy aroma (Colonia et al., 2023). The aroma of spirulina is attributed to various volatile organic compounds, including hydrocarbons, aldehydes, ketones, nitrogen-containing compounds, esters, and furans (Podgórska-Kryszczuk, 2024).

In terms of taste, F1 was the most preferred formula compared to other formulas. F1 was in the range of like moderately to like very much for the taste attributes. The average taste preference value in F1 also differed significantly from those of F2 and F3. F1 had the most dominant soybean tempeh taste and the weakest spirulina taste compared to the other formulas. This study indicated that the panelists preferred F1, which contained the highest proportion of tempeh flour (95%). Similar findings indicated that the panelists preferred the taste of cookies produced with tempeh flour to those made with other flours (Bakara et al., 2024). The results also indicated that F1, which contained the lowest percentage of spirulina (5%), had the highest taste preference. Similar results were obtained by Bosnea et al., (2021), who showed that panelists preferred cheese products with lower amounts of spirulina powder in terms of taste. Cheese containing 0.25% and 0.5% spirulina was predominantly preferred because of the milder characteristic taste of spirulina. Another study reported that

the snack bars containing the lowest percentage of spirulina (2%) were preferred by consumers in terms of sensory taste parameters (Lucas et al., 2020).

The texture aspect showed no significant differences among the three formulas. However, F1 had a slightly higher average texture preference than F2 and F3 did. The assessment of the preference level on the texture aspect was between slightly like and like moderately. The multigrain snack bar in this study had a dense, crumbly texture that was liked by the panelists. This texture is similar to that of most snack bar products. Although the manufacturing process of snack bars may be perceived as easy, it has been found that including functional ingredients can negatively impact sensory attributes, particularly texture (de Melo et al., 2020; Lucas et al., 2020). In terms of adding tempeh flour and spirulina powder, the results of this study show that F1 is the best formula that can produce a better texture than the other formulas.

In the overall hedonic test, the panelists preferred F1 over the other formulas. The difference test analysis also showed that the preference level for F1 was significantly different from that of F2 and F3. The overall panelist assessment of F1 was in the range of slightly to moderately liked. In this study, F1, which contained 95% tempeh flour and 5% spirulina powder, was the formulation most preferred by the panelists based on overall aspects. It is also suspected that the panelists'

acceptance of this tempeh flour and spirulina-based snack bar product can be improved by adding flavorings, masking agents, or a combination of other ingredients. Research has shown that adding dried fruits, nuts, honey, and cinnamon powder to cereal bars can mask the unpleasant odor of spirulina (Ottombrino et al., 2025). Furthermore, the addition of sunflower oil, salt, and whey powder to dragee coatings for corn snacks with spirulina enhances taste and overall acceptability, resulting in high sensory scores (Bayat Tork et al., 2022). The use of microencapsulation technology is also believed to increase the acceptance of food products. Previous research has shown that microencapsulation processes using maltodextrin, alginate, or whey protein effectively mask the aroma and taste of spirulina, thereby improving sensory acceptance in biscuits and dairy products and allowing for higher spirulina content without unpleasant aftertastes (Castillo-Barzola et al., 2025; Nourmohammadi et al., 2020; Paula da Silva et al., 2021).

### Nutritional Content

Table 3 shows the results of the nutritional analysis. The findings indicate that the moisture and crude fiber contents were not significantly different. Nevertheless, there were significant differences in the ash, lipids, protein, carbohydrates, and iron content.

**Table 3.** Results of the nutritional content of multigrain snack bar

Parameter	Unit	Formula			p-value
		F1	F2	F3	
Moisture	%	8.42±0.14a	9.44±0.16 a	8.77±0.13a	0.120
Ash	%	1.83±0.03a	2.06±0.05b	2.10±0.05b	0.021
Fat	%	14.79±0.03a	14.56±0.22a	15.64±0.23b	0.022
Protein	%	17.63±0.16a	17.39±0.09a	18.78±0.16b	0.003
Carbohydrate	%	65.75±0.11a	65.99±0.37a	63.48±0.44b	0.009
Iron	mg/100 g	3.24±0.02a	2.74±0.02b	3.16±0.03c	0.000
Crude fiber	%	3.86±0.03a	3.93±0.02a	3.89±0.03a	0.100

*a,b,c Means of the same row with differing superscripts are significantly different (P<0,05), F1=95:5, F2=90:10. F3=85:15.*

Moisture content refers to the proportion of water in a sample. The moisture content of a product can significantly influence its shelf life. It is also essential to the physical structure of food products (Mafe et al., 2024). Based on this study, the moisture content of this snack bar ranged from 8.42% to 9.44%. The lowest

moisture content was observed in F1. Statistical analysis did not reveal any significant differences in the water content between the formulas. The Indonesian National Standardization Agency has yet to establish minimum and maximum content thresholds for snack bar products. The water content of the

samples was suspected to be caused by other ingredients, except tempeh flour and spirulina powder. The significant presence of brown sugar and honey in the formulation likely contributed to the elevated moisture content of the product. Similarly, Lucas et al., (2020) showed that the water content in snack bar products with the addition of spirulina ranged from 10.75% to 12.68%. This high moisture content was due to the addition of brown sugar, glucose syrup, and water to the formulation.

Ash is an inorganic residue produced by complete combustion. The mineral content of the ingredients determines the ash content of food products. The ash content observed in this study ranged from 1.83% to 2.10%. Statistical analysis revealed that the ash content in F1 was significantly different from that in F2 and F3. F3, which contained the highest concentration of Spirulina powder, exhibited the highest ash content among the other formulas. Similarly, Zaidi et al., (2025) found that incorporating Spirulina into the cookie mix resulted in an ash content of 3,78%. In contrast, the control, which did not include Spirulina, had an ash content of 1,58%.

In the present study, the fat content ranged from 14.56% to 15.56%. There was a significant difference in the fat content between the formulas. The highest fat content was observed in F3, which had the highest proportion of Spirulina powder. Spirulina contains small quantities of nutritious lipids. The lipid content of Spirulina platensis was 7.2%. Spirulina also contains high amounts of linolenic acid (ALA), linoleic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) (Senila et al., 2025). However, the high fat content in the formulation can also be attributed to other ingredients, such as peanut butter and seeds, which are known plant-based sources of fat (Joshi & Bisht, 2020; Sithole et al., 2022).

Based on this study, the protein content of the formulas varied from 17,39% to 18,78%. F3, which contained the most abundant Spirulina powder, had a significantly higher protein content than F1 and F2. Tork et al., (2022) reported that the corn snack containing spirulina exhibited a protein content 5,5 times greater than the control, with a significant increase in protein levels. Spirulina is a recognized marine ingredient characterized by its high-protein content. Spirulina powder comprises 55 70% protein (Anvar & Nowruzi,

2021; Priyanka et al., 2023). C-Phycocyanin is a significant phytochemical present in Spirulina, and is known for its high protein content (Grover et al., 2021). Spirulina and its processed products also contain essential and non-essential amino acids that contribute to protein synthesis, including valine, isoleucine, lysine, methionine, cysteine, threonine, tryptophan, phenylalanine, and tyrosine (Aleksandrovna et al., 2019; Tork et al., 2022). Consequently, they serve as a primary source of protein malnutrition.

The carbohydrate content in this study ranged from 63,48% to 65,99%. F1 and F2, which contained more tempeh flour, showed significantly higher carbohydrate content than F3. This is because tempeh flour has a higher carbohydrate content than Spirulina powder. According to Ratnayani et al., (2025), tempeh flour contains 28,86% carbohydrates. Meanwhile, spirulina powder contains 12,7% to 17,8% carbohydrates (Priyanka et al., 2023). Carbohydrates are a significant source of energy in the human diet. Increased carbohydrate content is believed to enhance the overall energy content of food products (Campos et al., 2022).

The iron content of this snack bar varied from 2,74 to 3,24 mg/100 g. The results also showed that F1, which contained the highest amount of tempeh flour, had a significantly higher iron content than F2 and F3. A previous study reported that adding tempeh flour to gluten-free non-gluten pasta significantly increased its iron content. The highest tempeh flour content in that study (15%) resulted in 6,94 mg/100g of iron content (Sholichah et al., 2020). Tempeh flour contains 18,66 g/100 g of iron (Ratnayani et al., 2025). Therefore, tempeh flour could be an alternative food source to increase the iron content of food products.

There was no significant difference in the crude fiber content among the formulations. The crude fiber content of all formulas ranged from 3,86% to 3,93%. This result indicates that the addition of tempeh flour and spirulina powder did not significantly increase the fiber content. Additionally, the inclusion of rolled oats and seeds in the formulation may contribute to the fiber content of this snack bar. A previous study reported that the use of cereals and seeds in the preparation of a snack bar can contribute to its fiber content of the snack bar. The optimum formulation for making fiber-rich bars in that study consists of 54.57 g of cereals, 10.43 g of

seeds, and 35 g of a binder. This fiber-rich bar contained 8.56 % fiber content (Bourekoua et al., 2023).

### Selected Formula

The selected formula was analyzed using an exponential comparison method. This approach serves as a decision-making technique designed to evaluate and rank alternatives, based on various criteria. This method has also been employed in prior research on to determine selected formulations for product development (Ghassani et al., 2022; Hanum & Nuraeni, 2024; Sari, 2024).

Formula F1, which comprises 95% tempeh flour and 5% spirulina powder, was the most effective formula in this study (ranking 1). Based on the hedonic aspect, F1 was the most preferred by the panelists in terms of color, aroma, taste, and texture. In terms of nutritional content, F1 also contained protein, iron, and fiber that met the criteria selected for this study. In conclusion, the selected formula for this study was F1.

### Nutrient Contribution of the Selected Multigrain Snack Bar to the Adolescent's Needs

The nutritional content of the selected snack bars (F1) was calculated as a percentage contribution based on the nutritional label guidelines (NLG) and recommended dietary allowance (RDA). The calculated results are presented in Table 4.

Adolescents are incorporated into the general population in the NLG table reference (Badan Pengawas Obat dan Makanan, 2016). The analysis indicated that, per 100 g of the F1 snack bar, the composition contributing to the NLG included 22% energy, 22% fat, 29% protein, 20% carbohydrates, 15% iron, and 13% fiber. The findings indicate that the F1 snack bar meets the dietary source claim requirements for protein, iron, and fiber based on the claim regulations of the Indonesian Food and Drug Supervisory Agency (Badan Pengawas Obat dan Makanan, 2022).

**Table 4.** Contribution of nutritional content to the NLG and RDA

Nutrient	Nutrient content per 100g	Nutrient content per 20g	% NLG per 100 g	% RDA per 20 g				Commercial multigrain bar (20 g) <sup>1</sup>
				Boys		Girls		
				13-15 y.o	16-18 y.o	13-15 y.o	16-18 y.o	
Energy (kcal)	466.61	93.32	22	4	4	5	4	90.0
Fat (g)	14.79	2.96	22	4	3	4	4	3.5
Protein (g)	17.63	3.53	29	5	5	5	5	2.0
Carbohydrate (g)	65.75	13.15	20	4	3	4	4	15
Iron (mg)	3.24	0.65	15	6	6	4	4	-
Fiber (g)	3.86	0.77	13	2	2	3	3	1

NLG = nutritional label guidelines, RDA = recommended dietary allowance, <sup>1</sup>Nutritional value of "Fitbar" by Kalbe Nutritionals

The nutrient contribution of this selected multigrain snack bar per serving was also assessed based on the Indonesian RDA for adolescents aged 13-15 and 16-18 years, encompassing both genders (Kementerian Kesehatan, 2019). The snack bar had a serving size of 20 g, which aligns with the serving sizes of comparable products available on the market and in a previous study (Khoiriyah et al., 2025). The analysis indicated that a single serving (20 g) of this multigrain snack bar provides 4-5% of the RDA for energy, 3-4% for fat, 5% for protein, 3-4% for carbohydrates, 4-6% for iron, and 2-3% for fiber. This snack bar is recommended for

consumption during the snack time. The energy requirement for snacking typically accounts for 10-15% of the daily caloric intake. This snack bar is recommended to be consumed in three servings to fulfill the calorie requirements from snacking. Therefore, three servings of this product will contribute approximately 12-15% of the RDA for energy, 15% for protein, 12-18% for iron, and 6-9% for fiber. This contribution is considered sufficient to cover the nutritional needs during snack time. However, adolescents should still obtain the rest of their nutrient needs from other main meals. In addition, the study results showed that multigrain snack bars

had a higher protein content than commercial products. However, their fat, carbohydrate, and fiber contents are lower than those of commercial bars.

The multigrain snack bars resulting from this research have the potential to be produced by home industries or MSMEs. The product's manufacturing process involves relatively simple steps, and the key ingredients are readily accessible in the local market. Tempe has a high potential for sustainable product development in Indonesia. Tempe is a source of vegetable protein that is widely produced by the local Indonesian industry (Romulo & Surya, 2021). Its industrial use can also support local soybean farmers and enhance the potential of traditional Indonesian food (Putri et al., 2025). In addition, spirulina is known to have a high macronutrient and micronutrient content, making it a potential alternative food source and the future of the food industry (Podgórska-Kryszczuk, 2024). However, the challenge lies in spirulina's relatively high cost and availability, which depend on controlled aquaculture systems. The optimal formulation in this study used only 5% Spirulina, minimizing costs while increasing the nutritional content of the product. Therefore, the addition of locally cultivated spirulina in the future could improve the affordability and sustainability of the product.

Future research should focus on conducting product stability and shelf-life testing to evaluate changes in nutrient retention, texture, and microbial safety during storage. Organoleptic testing can also use adolescent panelists to assess product acceptability. Efficacy studies, including animal or human trials, are also needed to determine the actual impact of the product on protein and iron status in adolescents. Furthermore, a cost-benefit analysis can be conducted to support the implementation of community nutrition programs and MSME-level production.

## Conclusion

The incorporation of tempeh flour and spirulina in the three formulations resulted in significant differences in color, aroma, taste, and overall acceptability. F1 was the optimal formulation, providing 17.63% protein, 3.24 mg/100 g iron, and 3.86% fiber, which met the nutrient-source claim standards. A single serving of F1 provides

4-5% of the RDA for energy. This study successfully addressed its primary objective of developing a multigrain snack from tempeh flour and Spirulina, containing protein, iron, and fiber, to meet the snacking needs of adolescents.

The novelty of this study lies in the combination of tempeh flour and spirulina to create a nutrient-dense snack targeted at adolescents. Future research could involve adolescent panelists in organoleptic testing and calculating product costs. Furthermore, further research is needed to assess shelf-life stability, animal testing, and the product's clinical effects in adolescents to confirm its potential to improve nutritional status.

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