April – June, 2026
Original Article
DOI: http://dx.doi.org/10.30867/action.v11i2.3218

AcTion: Aceh Nutrition Journal
Pages: 673 – 686 | p-issn 2527-3310; e-issn 2548-5741

Development and nutritional evaluation of a tempeh and sweet potato leaf-based functional beverage for adolescent nutrition

Pengembangan dan evaluasi nilai gizi minuman fungsional berbasis tempe dan daun ubi jalar untuk gizi remaja

Nur Khoiriyah[1*], Rizaluddin Akbar[2], Muhammad Zakaria[3]

[1] Nutrition Study Program, Universitas Muhammadiyah Cirebon, Cirebon, Indonesia. E-mail: nurkhoiriyah@umc.ac.id
[2] Nursing Science Study Program, Universitas Muhammadiyah Cirebon, Cirebon, Indonesia. E-mail: rizaludinakbar@umc.ac.id
[3] Nutrition Study Program, Universitas Muhammadiyah Cirebon, Cirebon, Indonesia. E-mail : bangzack410@gmail.com

***Correspondence Author:**
[1]Nutrition Study Program, Universitas Muhammadiyah Cirebon, Cirebon, Indonesia. E-mail: nurkhoiriyah@umc.ac.id

Article History:
Received: April 09, 2026; Revised: April 23, 2026; Accepted: May 12, 2026; Published: June 09, 2026.

Publisher:
Politeknik Kesehatan Aceh
Kementerian Kesehatan RI

Abstract

Adolescent anemia remains a nutritional problem in Indonesia. Anemia affects 16.2% of the population in the country. Tempeh and sweet potato leaves are rich in iron, protein, and antioxidants, making them beneficial for adolescent nutrition. Few studies have combined these two ingredients in beverages. This study aimed to develop a beverage product using tempeh and sweet potato leaves to support adolescent nutrition. This study was conducted from August to October 2025 using a completely randomized design with three replications. The proportions of tempeh to sweet potato leaves were 100:0 (F0, control), 90:10 (F1), 80:20 (F2), 70:30 (F3), and 60:40 (F4). The product formulation was conducted at the Nutrition Laboratory of the Universitas Muhammadiyah Cirebon. The analysis included sensory evaluation (30 semi-trained panelists), proximate, iron, and antioxidant content, formulation selection, and nutritional contribution to the needs of adolescents. Data were analyzed using ANOVA and Duncan's test. Significant differences were observed in color, aroma, taste, texture, overall preference, moisture, ash, fat, protein, iron, and antioxidant activity among the formulations ($p<0.05$). Meanwhile, carbohydrate content did not differ significantly ($p=0.184$). F1 was selected, yielding 3.43% protein, 4.84 mg/100 g iron, and 17494.73 ppm antioxidant activity (IC50). In conclusion, F1 is recommended as the best formulation to support adolescent nutrition.

Keywords: Anemia, adolescents, functional food, sweet potato leaves, tempeh

Abstrak

Anemia pada remaja masih menjadi masalah gizi di Indonesia. Anemia mempengaruhi 16,2% populasi. Tempe dan daun ubi jalar mengandung zat besi, protein, dan antioksidan, sehingga bermanfaat untuk gizi remaja. Hanya sedikit penelitian yang menggabungkan kedua bahan tersebut dalam bentuk minuman. Penelitian ini bertujuan untuk mengembangkan produk minuman yang terbuat dari tempe dan daun ubi jalar untuk mendukung gizi remaja. Penelitian ini dilakukan dari Agustus hingga Oktober 2025 menggunakan rancangan acak lengkap. Proporsi tempe dan daun ubi jalar adalah 100:0 (F0, kontrol), 90:10 (F1), 80:20 (F2), 70:30 (F3), dan 60:40 (F4). Formulasi produk dilakukan di Laboratorium Gizi Universitas Muhammadiyah Cirebon. Analisis meliputi evaluasi sensorik (30 panelis semi-terlatih), kandungan proksimat, zat besi, dan antioksidan, pemilihan formulasi, dan kontribusi zat gizi terhadap kebutuhan remaja. Data dianalisis menggunakan ANOVA dan uji Duncan. Terdapat perbedaan signifikan pada warna, aroma, rasa, tekstur, preferensi keseluruhan, kadar air, abu, lemak, protein, zat besi, dan aktivitas antioksidan di antara formulasi ($p<0,05$). Sementara itu, kandungan karbohidrat tidak berbeda secara signifikan ($p=0,184$). F1 adalah formulasi yang terpilih, menghasilkan protein 3.43%, zat besi

4.84 mg/100 g, dan aktivitas antioksidan 17494.73 ppm (IC50). Kesimpulannya, F1 direkomendasikan sebagai formulasi terbaik untuk mendukung gizi remaja.

Kata Kunci: Anemia, remaja, pangan fungsional, daun ubi jalar, tempe

Introduction

Adolescence is a critical developmental period characterized by increased nutritional requirement. Inadequate dietary intake during this stage elevates the risk of malnutrition, particularly micronutrient deficiencies, with anemia being one of the most prevalent nutritional disorders (Beckwith et al., 2024). Anemia is defined as a condition in which hemoglobin (Hb) concentration falls below the normal physiological level.

According to the World Health Organization, the global prevalence of anemia among women aged 15–49 years was 30.7% in 2023 (World Health Organization, 2023). Anemia is also a significant public health concern among Indonesian adolescents. The 2023 Indonesian Health Survey reported that 16.2% of the population was affected by anemia, with a prevalence of 31.8% among children and adolescents (Kementerian Kesehatan Republik Indonesia, 2023). During adolescence, anemia is associated with numerous adverse health outcomes, including impaired cognitive performance, reduced physical capacity, and compromised immune function (Samson et al., 2022). Therefore, addressing adolescent anemia is a public health priority and aligns with Sustainable Development Goal 2 (Zero Hunger), which aims to reduce the global prevalence of anemia by 50% by 2030 (from approximately 30% in 2012 to 15 %) (Merid et al., 2023).

Unhealthy dietary behaviors are major contributors to anemia in adolescents, particularly diets characterized by insufficient protein and iron intake (Pibriyanti et al., 2021; Wahyu et al., 2023). Both nutrients play essential roles in the synthesis of hemoglobin. Protein constitutes the globin component of hemoglobin, whereas iron forms the heme group, which is responsible for oxygen binding. In addition, protein is required for the synthesis of transferrin, the primary iron transport protein in the body (Brittenham et al., 2023; Hooda et al., 2014). Another dietary concern is the inadequate consumption of antioxidant-rich foods. Evidence indicates that adolescents exhibit lower combined dietary antioxidant index scores (−0.67) than children (−0.45) (Chen & Shi, 2025). Antioxidants neutralize reactive oxidants by donating electrons without generating additional radical species (Manful et al., 2025). In individuals with anemia, the balance between oxidative stress and antioxidant defense mechanisms may become disrupted. Previous research has demonstrated that individuals with anemia have higher oxidant levels than healthy individuals of comparable ages and sexes (Shafiee et al., 2024). Consequently, enhancing antioxidant intake may be an important strategy for preventing and managing anemia.

The development of healthier and more nutrient-dense food products is a practical approach to addressing anemia among adolescents. The key nutritional components to consider in product development are protein, iron, and antioxidants. Tempeh and sweet potato leaves are promising local food ingredients with substantial nutritional potentials. Tempeh is a fermented soybean product produced using the fungus Rhizopus oligosporus and is a rich source of protein. The protein content of soybean tempeh has been reported to range from 30.39% to 42.29% (Tan et al., 2024). In addition, tempeh contains vitamin B12 (0.59 mg/100 g) and iron (4.0 mg/100 g) (Kementerian Kesehatan, 2020). Previous studies have demonstrated the potential of tempeh in the prevention and management of anemia in children and adolescents (Nurlia et al., 2025). Sweet potato leaves are also nutritionally valuable, containing niacin, vitamins B6, B2, B1, C, and E, and minerals such as sodium, magnesium, and phosphorus (Ranteallo et al., 2023). Furthermore, sweet potato leaves possess considerable antioxidant activity owing to the presence of bioactive compounds, including anthocyanins, polyphenols, and flavonoids (Nguyen et al., 2021). Previous research has reported the potential of sweet potato leaves in preventing anemia, as evidenced by improvements in hemoglobin concentrations (Jubaedah et al., 2024).

Tempeh and sweet potato leaves can be incorporated into various processed food products, including functional beverages. Functional beverages are drinks enriched with

bioactive compounds and targeted nutrients that provide scientifically supported health benefits (Alalwan, 2025). Beverage products are particularly popular among adolescents and constitute a substantial component of their daily diet (Lara-Castor et al., 2024). Therefore, incorporating local ingredients such as tempeh and sweet potato leaves into beverage formulations may enhance their nutritional quality, particularly with respect to protein, iron, and antioxidant content, thereby supporting the nutritional needs of adolescents.

Previous studies have investigated beverage products formulated using tempeh or sweet potato leaves individually (Hamidatun et al., 2023; Mubarok & Nurkhasanah, 2022; Windardi & Dewi, 2025). However, research examining the combined application of these two ingredients in a functional beverage specifically developed for adolescents is limited. Moreover, evidence regarding the nutritional and sensory characteristics of such formulations, particularly their protein, iron, and antioxidant potentials, is still scarce. Therefore, this study aimed to develop a functional beverage formulated from tempeh and sweet potato leaves and evaluate its sensory properties and nutritional composition as a potential health-promoting beverage for adolescents. The findings of this study may contribute to the development of innovative, adolescent-oriented functional beverages based on locally available food sources.

Methods

Research design

This study employed a laboratory experiment with a single-factor, completely randomized design with five treatments. The factors used were the ratios of the main ingredients of tempeh and sweet potato leaves in the formulation. The other ingredients and product manufacturing steps were the same for all treatments. Each sample treatment was labeled with three random-digit codes, and each treatment was replicated in triplicate. The research was conducted between August and October 2025. Product preparation and sensory evaluation were performed at the Nutrition Department Laboratory of Universitas Muhammadiyah Cirebon. Chemical analyses, including moisture, ash, protein, fat, carbohydrate, iron content, and antioxidant capacity, were conducted at Chem-Mix Pratama Laboratory in Yogyakarta. This study was approved by the Ethics Committee (number: 347/KEPK). ITEKESMA/IX/2025, issued by the Ethics Commission of Mahardika Institute of Technology (KEP Mahardika).

Sample preparation

The beverage product formulation is shown in Table 1. All the ingredients used were obtained from markets and local farmers in Cirebon, West Java, Indonesia. The ingredients used to make the beverage product included tempeh, sweet potato leaves, ginger, corn sugar, skim milk powder, skim milk, Carboxymethyl Cellulose (CMC), water, and salt. This study utilized combinations of tempeh and sweet potato leaves in varying proportions (F1=90:10, F2=80:20, F3=70:30, and F4=60:40 by weight). Formula F0 (100:0) is the control formula in this study, with a 100% tempeh and 0% sweet potato leaves ratio.

Table 1. Formulation (g) of beverage product with different proportions of tempeh and sweet potato leaves (100:0, 90:10, 80:20, 70:30, 60:40 by weight)

Ingredient	Formula (g)				
	Control (F0) (100:0)	F1 (90:10)	F2 (80:20)	F3 (70:30)	F4 (60:40)
Tempeh	300	270	240	210	180
Sweet potato leaves	0	30	60	90	120
Ginger	5	5	5	5	5
Corn sugar	14	14	14	14	14
Skim milk powder	17	17	17	17	17
Skim milk liquid	30	30	30	30	30
Water	200	200	200	200	200
Salt	0.2	0.2	0.2	0.2	0.2
CMC	0.8	0.8	0.8	0.8	0.8

The beverage product preparation process begins with steaming tempeh for 30 min and blanching sweet potato leaves for 1 min. Tempeh, sweet potato leaves, ginger, and water were then blended and filtered through a sieve. CMC solution, corn sugar, skim milk powder, salt, and liquid skim milk were combined to form a homogeneous mixture. The mixture was then boiled over medium heat for 2 min. The finished beverage product samples were then placed in 250 ml bottles and stored at a chill temperature of 2-4 ^{0}C.

Sensory Test

Sensory evaluation was performed using a hedonic test involving 30 semi-trained panelists selected through purposive sampling. The test was performed in duplicate. The panelists were undergraduate nutrition students at Universitas Muhammadiyah Cirebon who had received training in sensory evaluation methods. The panelists who participated in this test met the inclusion criteria, including the absence of allergies, good health status, no olfactory impairments, and no color vision deficiencies. The sensory evaluation results predominantly represent the answers of a non-representative adolescent population.

The panelists received an explanation and signed informed consent before participating in this test. The parameters evaluated in the hedonic test were color, aroma, taste, texture, and overall preference. The evaluation utilized a 9-point hedonic scale, with 9 indicating the highest level of preference and 1 indicating the lowest, corresponding to responses from 'very dislike' to 'very like.' The panelists were seated in a controlled organoleptic testing environment with adequate lighting and no odor. A hedonic test was performed on samples of the beverage products. Each beverage sample was labeled using randomly generated three-digit codes to minimize bias during the evaluation. The panelists were blinded to the formulation composition during the sensory assessment. During the assessment, each panelist was provided with drinking water to cleanse their palate before testing the product samples.

Chemical analysis

Chemical analyses, including moisture, ash, fat, protein, carbohydrate, iron content, and antioxidant activity, were performed in triplicate. Moisture content was determined using the oven-drying method according to the Indonesian National Standard (SNI 8217:2015). Ash content was analyzed by the dry ashing (incineration) method, as specified in SNI 01-2891-1992. The lipid content was measured using the Soxhlet extraction method. The protein content was determined using the Kjeldahl method through total nitrogen quantification, followed by conversion to crude protein using an appropriate conversion factor. The carbohydrate content was calculated by difference, and the total energy value was estimated using standard Atwater conversion factors. The iron (Fe) concentration was quantified using spectrophotometric analysis to ensure analytical accuracy and sensitivity. Antioxidant capacity was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay to assess free radical inhibition activity.

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 selected formulation was determined based on the lowest total score obtained from ranking analysis.

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. 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.

Statistical analysis

Data were processed using Microsoft Excel and SPSS for Windows software. Sensory and chemical parameters were evaluated using one-way analysis of variance (ANOVA) to assess the effects of varying proportions of tempeh and sweet potato leaves. Normality and homogeneity assumptions were satisfied. Therefore, a parametric test, a one-way ANOVA, was applied. When significant differences were detected, Duncan's multiple range test was used for post-hoc comparisons. Statistical significance was set at $p < 0.05$ (95% confidence interval).

Result and Discussion

Sensory Testing Results

This study conducted a sensory analysis using a hedonic test to assess the panelists' preferences for the beverage samples. A higher score indicates a greater product preference among the panelists. Figure 1 presents the results of the hedonic test, and Figure 2 shows the final beverage products. One-way ANOVA indicated significant differences in color, aroma, taste, texture, and overall preference, with p-values < 0.05 for all variables. Therefore, Duncan's post hoc test was performed to identify significant differences in the mean scores among the treatment groups, as indicated by different superscript letter notations across the formulations.

Figure 1 shows that formulations containing higher proportions of sweet potato leaves tended to receive lower color-acceptance scores. F1 had a higher color preference score than F2, F3, and F4 did. This finding suggests that a more intense green color may reduce the visual appeal and consumer acceptability. Similar trends have been reported in previous studies on ice cream and biscuit products enriched with sweet potato leaves (Hartati et al., 2021; Pakpahan et al., 2025). The green color observed in this study was associated with the chlorophyll pigments naturally present in sweet potato leaves (daGama et al., 2023).

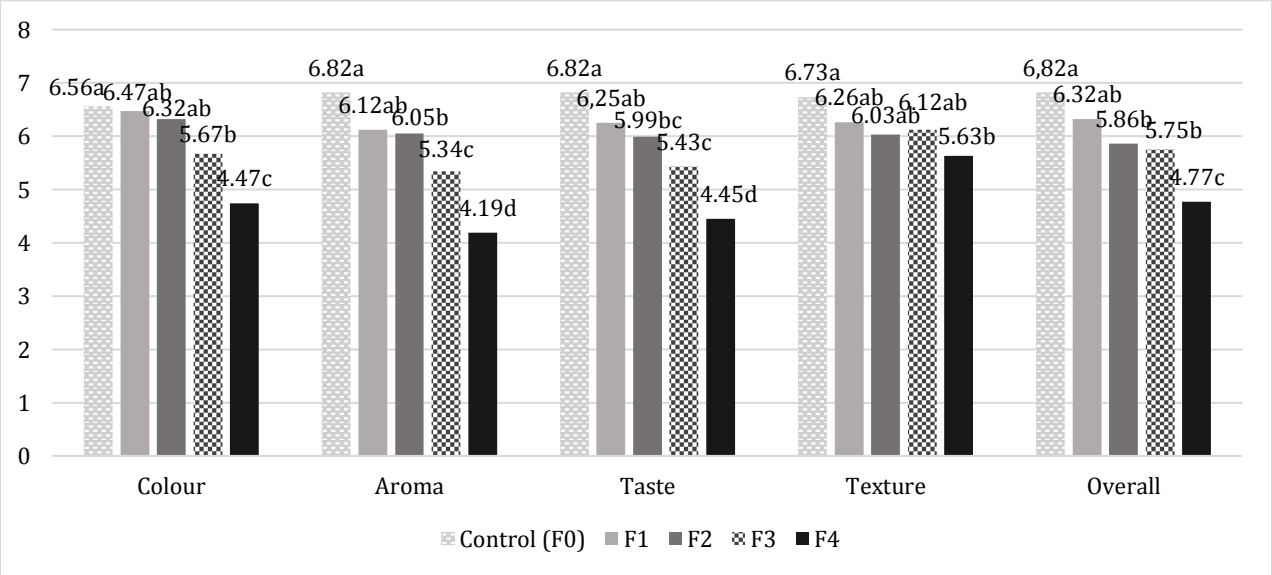

Figure 1. Results of hedonic sensory tests on beverage products made from tempeh and sweet potato leaves

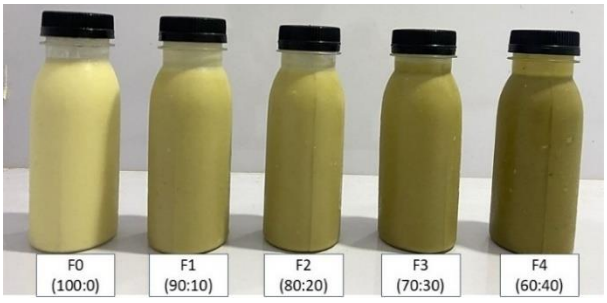

Figure 2. Beverage products made from tempeh and sweet potato leaves

Aroma preference varied significantly among the formulations (p = 0.000). The results also indicated that increasing the amount of sweet potato leaves was associated with a decreased aroma preference. This lower preference may be attributed to the increasingly identifiable leafy aroma resulting from the higher inclusion of sweet potato leaves in the formulation. The characteristic leafy aroma of sweet potato leaves is mainly associated with volatile organic compounds, including organic sulfides and terpenoids (Gao et al., 2025). Other compounds, such as β-caryophyllene, α-caryophyllene, and δ-cadinene, may also contribute to the aroma profile of the fruit (Marques et al., 2022).

Taste preference differed significantly among the formulations (p = 0.000). The results suggest that reducing the sweet potato leaf content and increasing the tempeh concentration improved taste preference. A similar finding was reported in a previous study, in which the

addition of tempeh and reduction of sweet potato content increased the cookie taste scores (Mushollini et al., 2024). Peptides produced during tempeh fermentation enhance umami flavor and generate a creamy mouthfeel, supporting the use of tempeh in food products to improve flavor and consumer acceptance (Amin et al., 2020). However, sweet potato leaves may impart bitter, astringent, and grassy tastes; therefore, increasing their concentration may reduce the taste preference. Secondary metabolites, including flavonoids, phenolics, and alkaloids, may contribute to the bitter and astringent taste of leafy plants (Ye et al., 2022).

The texture differed significantly among the formulations ($p = 0.047$). The texture of F1 was preferred to those of F2, F3, and F4. These results suggest that incorporating sweet potato leaves at low concentrations may improve the texture by functioning as a natural thickening agent, thereby enhancing water retention and overall texture. This effect may be attributed to the naturally occurring polysaccharides and fibers in sweet potato leaves (Liu et al., 2024). However, excessive addition may produce an overly dense texture, which could decrease consumer preferences (Hu et al., 2022).

Overall preference scores showed a statistically significant effect of formulation ($p = 0.000$). Formula F1 was more preferred (6.32) than F2, F3, and F4 (4.77–5.86). F1 also showed a preference score comparable to that of F0. Formula F1, which contained the lowest proportion of sweet potato leaves, remained acceptable to the panelists. Hu et al. (2022) reported similar findings, showing that steamed bread prepared with a small amount of sweet potato leaf powder (2%–10%) remained acceptable. Other studies have also shown that the addition of 5–10% sweet potato leaf extract produced the highest preference scores compared to higher concentrations (Hartati et al., 2021).

Panelists' acceptance of this tempeh- and sweet potato leaf-based beverage may be improved by adding flavoring agents or other ingredient combinations. Luo et al. (2020) found that flavoring agents such as xylitol, ascorbic acid, apple essence, and maltodextrin modified the color, taste, and sensory properties of sweet potato leaf powder-based beverages. Moreover, culinary methods such as blanching and drying have been reported to reduce the bitterness of sweet potato leaves, thereby improving their flavor and texture (Lawal et al., 2022). These processes are also known to help preserve the nutrient and antioxidant content. Therefore, future studies on beverage products made from tempeh and sweet potato leaves should consider flavoring agents, complementary ingredients, and processing methods to improve their overall sensory acceptability.

Chemical Content

Table 2 presents the chemical analysis results of the beverage products made from tempeh and sweet potato leaves in different formulations. The results showed that F4 had the highest moisture content at 80.89% ($p = 0.000$). Increased sweet potato leaf content and reduced tempeh content increased the moisture levels. The observed moisture content may be attributed to the substantial presence of water, liquid skim milk, and sweet potato leaves in the formulation. In most beverage products, the moisture content is high because of the addition of water or other water-rich ingredients. Similarly, Ogori et al. (2021) reported that the moisture content of beverages formulated from soybeans and malted yellow corn ranged from 80.50% to 85.0%.

Table 2. Results of the chemical content of beverage products

Parameter	Formula[1]					p-value
	Control (F0)	F1	F2	F3	F4	
Moisture (%)	79.19±0.09^{a}	79.32±0.17^{a}	80.18±0.07^{b}	80.76±0.13^{c}	80.89±0.01^{c}	0.000
Ash (%)	0.86±0.01^{a}	0.94±0.02^{b}	1.05±0.05^{c}	1.22±0.03^{d}	1.27±0.01^{d}	0.000
Fat (%)	4.80±0.13^{a}	4.45±0.00^{b}	4.10±0.10^{c}	3.91±0.06^{cd}	3.71±0.02^{d}	0.000
Carbohydrate (%)	11.43±0.13^{a}	11.75±0.32^{a}	11.55±0.03^{a}	11.29±0.12^{a}	11.36±0.01^{a}	0.184
Protein (%)	3.71±0.08^{a}	3.43±0.01^{b}	3.13±0.02^{c}	2.82±0.10^{d}	2.78±0.01^{d}	0.000
Iron (mg/100g)	3.73±0.01^{a}	4.84±0.00^{b}	5.23±0.03^{c}	5.70±0.04^{d}	6.31±0.03^{e}	0.000
IC50 (ppm)	20131.00± 13.61^{a}	17494.73± 404.94^{b}	13086.91± 50.40^{c}	9124.76± 18.86^{d}	7710.05± 38.38^{e}	0.000

[1]Formulations ratios of tempeh and sweet potato leave (F0=100:0, F1=90:10, F2=80:20, F3=70:30, F4=60:40); ^{a,b,c,d,e} Mean values with different letters in the same row indicate a significant difference at $\alpha = 5\%$.

The ash content differed significantly across the formulations (p = 0.000), with the highest ash content observed in F4 (1.27%). The results showed that the addition of sweet potato leaves to the mixture increased the ash content. This finding is consistent with that of Maretta et al. (2021), who reported that biscuits containing 7.5% purple sweet potato leaves had higher ash content (2.8%) than those containing 2.5% and 5% purple sweet potato leaves. Ash content also serves as an indicator of the mineral composition of food ingredients. The increase in ash content with increasing amounts of sweet potato leaves in the formulation may be attributed to the mineral content of the leaves. Sweet potato leaves are a source of minerals, particularly calcium, potassium, magnesium, and iron (Ranteallo et al., 2023).

The fat content differed significantly among the formulations (p = 0.000). Formula F4, which contained the highest proportion of sweet potato leaves, had the lowest fat content at 3.71%. Sweet potato leaves contribute only small amounts of fat to the diet. Across different harvesting stages, the fat content of sweet potato leaves has been reported to range from 2.9% to 3.7% (Suárez et al., 2020). In contrast, tempeh has a higher fat content, ranging from 10.81% to 12.79% (Maitresya & Surya, 2023). In the present study, sweet potato leaves replaced tempeh, which has a higher fat content, resulting in lower fat levels in formulas containing higher proportions of sweet potato leaves. Similar results were reported for cookies containing more sweet potato flour and less tempeh flour, which had lower fat content (4.19%–4.98%) than those containing more tempeh flour (5.15%–7.61%) (Mushollini et al., 2024).

The carbohydrate content was similar across the formulations (p = 0.184). The variations in the proportions of tempeh and sweet potato leaves did not significantly affect the carbohydrate levels. Similar findings have been reported for other composite foods, in which the carbohydrate content remained within a consistent range despite variations in the proportions of tempeh and sweet potato leaves (Maretta et al., 2021). These results may be due to the relatively comparable carbohydrate content of tempeh and sweet potato leaves. Previous research has indicated that the carbohydrate content of tempeh on a dry matter basis ranges from 33.85% to 44.70%, whereas that of sweet potato leaves ranges from 48.50% to 55.65% (Omoba et al., 2020; Yuliani et al., 2022).

The protein concentration varied significantly among the formulations (p = 0.000). F1 had a higher protein content (3.43%) than F2, F3, and F4. This study showed that formulations with higher tempeh content had higher protein contents. These findings are consistent with those of Setiawan et al. (2021), who reported that pumpkin cream soup formulated with tempeh had a higher protein content (21.42%–31.85%) than formulas without tempeh (9.76%–10.14%). The increase in protein content may be attributed to the naturally high protein content of the tempeh. Tan et al. (2024) reported that soybean tempeh contains 42.29% protein. Moreover, tempeh protein is more digestible than soybean protein because of the proteolytic enzymes produced by Rhizopus spp. during fermentation (Wu et al., 2025). Adequate protein intake contributes to hemoglobin synthesis and red blood cell formation. Proteins support the production of globin chains, which are structural components of hemoglobin (Giardina, 2022). Proteins also form transferrin, which transports iron for erythropoiesis. However, the risk of anemia is influenced by multiple factors, including iron bioavailability, dietary inhibitors, and overall nutritional status (Soni et al., 2025).

The iron concentrations differed significantly among the formulations. Formula F4 had the highest iron content (6.31 mg/100 g). The present study demonstrated that increasing the proportion of sweet potato leaves in the formulation increased the iron content. Similar findings have been reported in previous studies, showing that the incorporation of sweet potato leaves can increase the iron content. For example, the iron content of a sweet potato leaf-enriched milkshake was reported to be 4.02 mg/100 g (Mubarok & Nurkhasanah, 2022). This value was higher than that of standard soybean milkshake products (0.07 mg/100 g) and soybean milkshakes formulated with flaxseeds (1.5 mg/100 g) (Kalaiarasi & Kalamani, 2024). Sweet potato leaves are considered plant-based sources of iron. Nguyen et al. (2021) reported that the iron content of sweet potato leaves ranges from 1.9 to 21.8 mg/100 g on a dry basis. Similarly, Gouekou et al. (2021) reported that the iron content of sweet potato leaves ranged from 22.48 to 39.90 mg/100 g under different cooking conditions. Furthermore, iron-rich sweet potato

leaves have been reported to enhance iron absorption and support hemoglobin synthesis, making them useful for the dietary management of iron-deficiency anemia in both animal and human studies (Gouekou et al., 2021).

Iron is a fundamental micronutrient in the human body. Iron homeostasis is primarily regulated by intestinal absorption, as humans lack active iron excretory mechanisms. Therefore, optimal intestinal iron bioavailability is essential for reducing the risk of iron deficiency anemia. Iron in food occurs in two forms: heme and nonheme iron. Heme iron, primarily derived from animal-source foods, has a higher bioavailability and absorption efficiency. In contrast, nonheme iron, commonly found in plant-based foods, has a lower bioavailability and is strongly affected by dietary enhancers and inhibitors of iron absorption (Piskin et al., 2022). Future studies should focus on developing food products that incorporate heme iron sources to improve iron bioavailability.

Antioxidant activity was assessed by determining the IC50 value using the DPPH assay. A lower IC50 value indicates greater antioxidant activity (Gulcin & Alwasel, 2023). Significant differences in antioxidant activity were observed among the formulations ($p = 0.000$). Formula F4 showed the highest antioxidant activity, with an IC50 value of 7710.05 ppm. This result indicates that increasing the amount of sweet potato leaves in the formula increased the antioxidant activity. Sweet potato leaves are rich in polyphenols, flavonoids, and anthocyanins, which are the major contributors to their antioxidant activity. Jia et al. (2022) reported that sweet potato leaves contain phenolic compounds ranging from 53.19 to 125.76 GAE/100 g and anthocyanins ranging from 3.22 to 109.60 mg/100 g. However, the beverage product exhibited very weak antioxidant activity, as indicated by the measured IC50 value, which is classified as very weak when exceeding 200 ppm (Farhansyah et al., 2025). This may be due to the highwater content of the beverage, which requires a greater amount of sample to achieve 50% inhibition.

Antioxidant activity is an important mechanism for alleviating oxidative stress (Chaudhary et al., 2023). Dietary intake is a modifiable factor for reducing oxidative stress, as regular consumption of antioxidant-rich foods may enhance endogenous defense mechanisms and reduce oxidative damage. Evidence indicates that the Composite Dietary Antioxidant Index (CDAI), an indicator used to assess antioxidant intake, is inversely associated with the prevalence of anemia (Wu et al., 2025). This finding suggests that a higher daily antioxidant intake is associated with a lower risk of anemia. Moreover, specific antioxidants, particularly vitamin C, promote nonheme iron absorption by converting ferric iron (Fe^{3+}) into the more bioavailable ferrous form (Fe^{2+}), thereby enhancing iron utilization and supporting hemoglobin synthesis (Deng et al., 2023). Therefore, dietary sources rich in antioxidants may synergistically support the prevention of anemia by mitigating oxidative stress. However, their role remains supportive rather than primary, compared to essential nutrients such as iron and protein.

Selected Formula and Nutrient Contribution

The formula selected in this study was determined using the exponential comparison method (Ghassani et al., 2022). Two aspects were considered in the analysis: sensory evaluation results (50%) and chemical composition (50%). The weight assigned to each parameter was based on its relevance to the objective of developing an alternative snack beverage with potential nutritional benefits in terms of protein, iron, and antioxidant content. In the sensory evaluation component, aroma (15%), taste (15%), and texture (15%) received the highest weights, followed by color (5%). In the chemical composition component, iron content (15%), protein content (10%), and antioxidant activity (IC50) (10%) were prioritized, whereas moisture, ash, fat, and carbohydrate contents each received a weight of 5%.

The analysis showed that F1 achieved the lowest total weighted score (2.40), indicating its best overall performance among all formulations. Based on hedonic evaluation, F1 was the most preferred formulation in terms of color, aroma, taste, and texture. Although F4 had higher iron content and antioxidant capacity, it received lower sensory acceptance scores, particularly for aroma, taste, and texture, which substantially influenced the overall ranking. As this product was developed as a beverage intended for adolescent consumption, sensory acceptability was considered as important as nutritional quality in determining the optimal formulation. Therefore, despite the superior nutritional value

of F4, its lower consumer acceptance reduced its overall feasibility as a potential adolescent snack beverage. In contrast, F1 exhibited a more balanced profile between sensory acceptability and nutritional composition, making it the selected formulation in this study.

The selected beverage formula (F1) was also analyzed to determine its percentage contribution based on the nutritional label guidelines (NLG) and recommended dietary allowance (RDA). The results are shown in Table 3. Adolescents are considered part of the general population in the NLG reference tables. This study found that the percentage contribution of F1 per 100 ml was 4.68% for energy, 6.64% for fat, 5.72% for protein, 3.62% for carbohydrate, and 21.82% for iron, respectively. These results demonstrate that F1 meets the Indonesian Food and Drug Authority criteria for a nutrient-rich claim for iron, which requires a minimum of 15% NLG per 100 ml. However, this product does not meet the criteria for a protein source claim, which requires a minimum of 10% NLG per 100 ml (Badan Pengawas Obat dan Makanan, 2022).

Table 3. Contribution of nutritional content of F1 to the NLG and RDA

Nutrient	% NLG[1] (100 ml)	% RDA[2] (100 ml)				Nutrient content (200 ml)	Commercial soybean beverage (200 ml)[3]
		Boys		Girls			
		13-15 y.o	16-18 y.o	13-15 y.o	16-18 y.o		
Energy (kcal)	4.68	4,19	3,80	4,91	4,79	201.15	145.90
Fat (g)	6.64	5,56	5,24	6,36	6,36	8.90	6.10
Carbohydrate (g)	3.62	3,36	2,94	3,92	3,92	23.50	16.80
Protein (g)	5.72	4,90	4,57	5,28	5,28	6.86	5.46
Iron (mg)	21.82	43,64	43,64	32,00	32,00	9.60	1.00

[1]NLG = nutritional label guidelines, [2]RDA = recommended dietary allowance, [3]Nutrient content of "V-soy" by Green Spot Co., Ltd

The nutrient contribution of the selected formula was evaluated against the Indonesian RDA for adolescents aged 13–15 and 16–18 years for both boys and girls (Kementerian Kesehatan, 2019a). The analysis showed that 100 ml of this beverage provides 4.19%–4.91% of the RDA for energy, 5.24%–6.36% for fat, and 2.94%–3.92% for carbohydrate (Table 3). This beverage is recommended for consumption as a snack beverage. Snacks generally contribute 10%–15% of the daily energy requirements. Adolescents are recommended to consume 229–343 ml of this beverage to meet their energy needs during snack time, equivalent to 230–345 kcal. This contribution is considered adequate to support nutritional intake during snack time.

Protein and iron are key nutrients required by adolescents to prevent anemia (Dilantika et al., 2024). The recommended protein requirement for adolescents ranges from 65 to 75 g/day, while the recommended iron requirement ranges from 11 to 15 mg/day for both boys and girls. By consuming 100 ml of this beverage, adolescents can meet 4.57%–5.28% of their protein requirements and 32.00%–43.64% of their iron requirements. Nevertheless, adolescents must obtain the remaining daily nutritional requirements from other meals. This study also found that the beverage had higher protein and iron content than a comparable commercial soybean beverage product (Table 3).

The tempeh and sweet potato leaf beverage product developed in this study also has the potential for production by home industries or micro, small, and medium-sized enterprises (MSMEs). The production method involves relatively simple procedures, and the main ingredients are readily available. Tempeh is widely produced in Indonesia and is a sustainable source of plant-based protein that supports local tempeh producers and soybean suppliers (Abdullah et al., 2025). Moreover, sweet potato leaves are readily available in the traditional markets. However, this food resource has not been optimally utilized in the production of shared food products, despite its substantial nutritional potential (Ranteallo et al., 2023). Increasing the proportion of sweet potato leaves may reduce consumer acceptance, particularly in terms of taste and aroma, which are important factors influencing real-world consumption behavior in adolescents. In this study, the optimal formulation was 90% tempeh and 10% sweet potato leaves. The results of this formula indicate that the overall sensory characteristics remained acceptable to the panelists while significantly increasing the product's iron content. Furthermore, the use of

locally sourced ingredients, such as tempeh and sweet potato leaves, may enhance the affordability and scalability of this beverage for community-based production and adolescent nutrition programs.

This study had several limitations. Organoleptic testing was conducted under controlled laboratory conditions and may not fully represent consumer preferences in actual consumption settings with a larger sample size. This study did not assess the shelf life or safety of long-term consumption of the products. Furthermore, the clinical effects of administering this product to adolescents with anemia have not yet been evaluated. Therefore, future studies should examine the shelf life and microbiological safety during storage to support more practical applications. Sensory analysis should also be conducted directly with adolescent panelists as target consumers of this product. In addition, future animal or human trials are needed to determine the product's actual effects on protein and iron status, as well as on anemia-related outcomes among adolescents. A cost-benefit analysis may also be conducted to support the adoption of community nutrition initiatives and industrial food production.

Conclusion

The findings of this study indicate that beverage formulations made from tempeh and sweet potato leaves in different proportions produced significant differences in color, aroma, flavor, texture, and overall acceptability. Formula F1 was selected as the optimal formulation, containing 79.32% moisture, 0.9% ash, 4.45% fat, 3.43% protein, 11.75% carbohydrate, 4.84 mg/100 g iron, and antioxidant activity of 17,494.73 ppm (IC50). Per 100 ml, F1 contributed 3.80%–4.79% of the RDA for energy. This study successfully developed a tempeh- and sweet potato leaf-based beverage containing protein, iron, and antioxidants to support the snacking needs of adolescents.

However, this study was limited to formulation, sensory evaluation, and nutrient analysis, and did not assess clinical outcomes related to anemia. Further animal and human studies are warranted to validate its potential efficacy. Future research should also examine shelf life, involve larger adolescent sensory panels, and evaluate the production costs.

Acknowledgements

The authors would like to express their sincere gratitude to the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for supporting this research.

References

Abdullah, F., Aprilia, H., & Nur, S. (2025). A systems approach to understanding the carbon emission pathways and economic benefits of tempeh SMEs supply chain in West Java. *Airlangga Journal of Innovation Management, 6*(2), 303–318. https://doi.org/10.20473/ajim.v6i2.72663

Alalwan, T. (2025). Consumer psychology in functional beverages: From nutritional awareness to habit formation. *Beverages, 11*(5), Article 126. https://doi.org/10.3390/beverages11050126

Amin, M. N. G., Kusnadi, J., Hsu, J.-L., Doerksen, R. J., & Huang, T.-C. (2020). Identification of a novel umami peptide in tempeh (Indonesian fermented soybean) and its binding mechanism to the umami receptor T1R. *Food Chemistry, 333*, Article 127411. https://doi.org/10.1016/j.foodchem.2020.127411

Badan Pengawas Obat dan Makanan. (2022). *Peraturan Badan Pengawas Obat dan Makanan Republik Indonesia Nomor 1 Tahun 2022 tentang pengawasan klaim pada label dan iklan pangan olahan*. Badan Pengawas Obat dan Makanan Republik Indonesia.

Beckwith, S., Chandra-Mouli, V., & Blum, R. W. (2024). Trends in adolescent health: Successes and challenges from 2010 to the present. *Journal of Adolescent Health, 75*(4 Suppl.), S9–S19. https://doi.org/10.1016/j.jadohealth.2024.04.015

Brittenham, G. M., Moir-Meyer, G., Abuga, K. M., Datta-Mitra, A., Cerami, C., Green, R., Pasricha, S.-R., & Atkinson, S. H. (2023). Biology of anemia: A public health perspective. *The Journal of Nutrition, 153*(Suppl. 1), S7–S28. https://doi.org/10.1016/j.tjnut.2023.07.018

Chaudhary, P., Janmeda, P., Docea, A. O.,

Yeskaliyeva, B., Faizal, A., Razis, A. F. A., Modu, B., Calina, D., & Shari, J. (2023). Oxidative stress, free radicals and antioxidants: Potential crosstalk in the pathophysiology of human diseases. *Frontiers in Chemistry, 11*, Article 1158198. https://doi.org/10.3389/fchem.2023.1158198

Chen, J., & Shi, C. (2025). Association between dietary antioxidant intake and overweight/obesity risk among children and adolescents: A cross-sectional analysis from NHANES 2011–2016. *Frontiers in Nutrition, 12*, Article 1540303. https://doi.org/10.3389/fnut.2025.1540303

da Gama, A. B. N., da Silva, E. A., de Araújo Júnior, V. C., Gonçalves Brito, O., da Costa, A. L., Yuri Cavasin, P., & Carvalho, E. E. N. (2023). Potential use of sweet potato leaves for human consumption. *Pesquisa Agropecuária Brasileira, 58*, e02991. https://doi.org/10.1590/S1678-3921.pab2023.v58.02991

Deng, J., Ramelli, L., Li, P. Y., Eshaghpour, A., Schuenemann, G. E., & Crowther, M. A. (2023). Efficacy of vitamin C with iron supplementation in iron deficiency anemia patients: A systematic review and meta-analysis. *Blood, 142*(Supplement 1), 1091. https://doi.org/10.1182/blood-2023-174801

Dilantika, C., Sitorus, N., & Saebah, N. (2024). The important role of iron, protein and vitamin C with the incidence of anemia. *Journal of Indonesian Specialized Nutrition, 1*(3), 121–130. https://doi.org/10.46799/jisn.v1i3.17

Farhansyah, M., Rostini, I., Rostika, R., & Pratama, R. I. (2025). Utilization of Pedada mangrove fruits (*Sonneratia* sp.) in the development of fruit juice drinks with carrageenan as a stabilizer. *Jurnal Perikanan Unram, 15*(5), 2558–2568. https://doi.org/10.29303/jp.v15i5.1736

Gao, Q., Chen, J.-N., Tian, Y.-L., Hao, M.-M., Sha, X.-L., Li, A., Peng, X., Yu, T., Gu, X.-J., & Xue, Y.-L. (2025). Effects of different crushing methods on the properties and flavor of selenium-enriched sweet potato leaves. *Food Chemistry: X, 26*, Article 102266. https://doi.org/10.1016/j.fochx.2025.102266

Ghassani, A. M., & Agustini, R. (2022). Formulation of flavor enhancer from shiitake mushroom (*Lentinula edodes*) with the addition of mackerel fish (*Scomberomorus commerson*) and tofu dreg hydrolysates. *Indonesian Journal of Chemical Science, 11*(3), 222–232.

Giardina, B. (2022). Hemoglobin: Multiple molecular interactions and multiple functions. An example of energy optimization and global molecular organization. *Molecular Aspects of Medicine, 84*, Article 101040. https://doi.org/10.1016/j.mam.2021.101040

Ginting, S. M. D., Februhartanty, J., & Khusun, H. (2024). Association between consumption of ultra-processed foods and beverages with nutritional status of private senior high school students in Pontianak, West Kalimantan, Indonesia. *World Nutrition Journal, 7*(2), 90–103. https://doi.org/10.25220/wnj.v07.i2.0011

Gouekou, D. A., Guédé, S. S., Gbogbo, M., Agbo, E. A., N'dri, D. Y., & Gbogouri, A. G. (2021). Impact of cooking conditions of sweet potato leaves (*Ipomoea batatas*) on the hematological and biochemical parameters of Wistar rats. *American Journal of Food and Nutrition, 9*(1), 23–30. https://doi.org/10.12691/ajfn-9-1-4

Gulcin, İ., & Alwasel, S. H. (2023). DPPH radical scavenging assay. *Processes, 11*(8), Article 2248. https://doi.org/10.3390/pr11082248

Hamidatun, H., Haniza, T., & Pujilestari, S. (2023). Karakterisasi fisikokimia dan organoleptik minuman sari tempe dengan penambahan jeruk nipis (*Citrus aurantiifolia*). *Jurnal Teknologi Pangan dan Kesehatan, 5*(2), 61–65.

Hartati, F. K., Hasanah, U., & Sucahyo, B. S. (2021). Physical, chemical and organoleptic quality of sweet potato leaves (*Ipomoea batatas* L.) ice cream. *IOP Conference Series: Earth and Environmental Science, 672*(1), Article 012063. https://doi.org/10.1088/1755-1315/672/1/012063

Hu, Y., Sun, H., & Mu, T. (2022). Effects of sweet potato leaf powder on sensory, texture, nutrition, and digestive characteristics of steamed bread. *Journal of Food Processing and Preservation, 46*(7), e16697. https://doi.org/10.1111/jfpp.16697

Jia, R., Tang, C., Chen, J., Zhang, X., & Wang, Z. (2022). Total phenolics and anthocyanins contents and antioxidant activity in four different aerial parts of leafy sweet potato (*Ipomoea batatas* L.). *Molecules, 27*(10), Article 3117. https://doi.org/10.3390/molecules27103117

Jubaedah, E., Suratmi, & Hermawan, M. H. (2024). The effect of giving sweet potato leaf-based functional drink to increase Hb levels. *Human Nutrition & Metabolism, 37*, Article 200280. https://doi.org/10.1016/j.hnm.2024.200280

Kalaiarasi, R., & Kalamani, R. (2024). Formulation and standardisation of functional flaxseed soymilk-shake. *Research Journal of Life Science, Bioinformatics, Pharmaceutical and Chemical Sciences, 10*(3), 1–11. https://doi.org/10.26479/2024.1003.01

Kementerian Kesehatan Republik Indonesia. (2019). *Peraturan Menteri Kesehatan Republik Indonesia Nomor 28 Tahun 2019 tentang angka kecukupan gizi yang dianjurkan untuk masyarakat Indonesia*.

Kementerian Kesehatan Republik Indonesia. (2020). *Tabel komposisi pangan Indonesia*. Kementerian Kesehatan Republik Indonesia.

Kementerian Kesehatan Republik Indonesia. (2023). *Survei kesehatan Indonesia 2023*. Kementerian Kesehatan Republik Indonesia.

Lara-Castor, L., Micha, R., Cudhea, F., Miller, V., Shi, P., Zhang, J., Sharib, J. R., Erndt-Marino, J., Cash, S. B., Barquera, S., Mozaffarian, D., Trichopoulou, A., Bas, M., Ali, J. H., El-Kour, T., Krishnan, A., Misra, P., Hwalla, N., Janakiram, C., ... Hakeem, R. (2024). Intake of sugar-sweetened beverages among children and adolescents in 185 countries between 1990 and 2018: Population-based study. *BMJ, 386*, e079234. https://doi.org/10.1136/bmj-2024-079234

Lawal, A. I., Raji, A. O., Osifuwa, A. O., & Akinoso, R. (2022). Quality characteristics of sweet potato leaves (*Ipomoea batatas* L.) as influenced by processing and storage conditions. *Croatian Journal of Food Science and Technology, 14*(2), 202–209. https://doi.org/10.17508/CJFST.2022.14.2.05

Liu, T., Xie, Q., Zhang, M., Gu, J., Huang, D., & Cao, Q. (2024). Reclaiming agriceuticals from sweetpotato (*Ipomoea batatas* [L.] Lam.) by-products. *Foods, 13*(8), Article 1180. https://doi.org/10.3390/foods13081180

Luo, D., Mu, T., Sun, H., & Chen, J. (2020). Optimization of the formula and processing of a sweet potato leaf powder-based beverage. *Food Science & Nutrition, 8*(6), 2680–2691. https://doi.org/10.1002/fsn3.1555

Maitresya, L. B., & Surya, R. (2023). Development of tempeh made from soybeans, black-eyed beans, and winged beans. *IOP Conference Series: Earth and Environmental Science, 1200*(1), Article 012008. https://doi.org/10.1088/1755-1315/1200/1/012008

Manful, C. F., Fordjour, E., Subramaniam, D., Sey, A. A., Abbey, L., & Thomas, R. (2025). Antioxidants and reactive oxygen species: Shaping human health and disease outcomes. *International Journal of Molecular Sciences, 26*(15), Article 7520. https://doi.org/10.3390/ijms26157520

Maretta, O. O., Sukardi, S., & Winarsih, S. (2021). Efek penggunaan tepung daun ubi jalar ungu dan tepung daun ubi jalar kuning terhadap karakteristik fisikokimia, organoleptik, dan aktivitas antioksidan pada cookies. *Food Technology and Halal Science Journal, 4*(2), 192–207. https://doi.org/10.22219/fths.v4i2.16603

Marques, T. S., Moreira, R. F. A., & Ayres, E. M. M. (2022). Characterization of the essential oils from leaves of different sweet potato cultivars grown in Brazil. *South African Journal of Botany, 144*, 18–22. https://doi.org/10.1016/j.sajb.2021.09.005

Merid, M. W., Chilot, D., Alem, A. Z., Aragaw, F. M., Asratie, M. H., Belay, D. G., & Kibret, A. A. (2023). An unacceptably high burden of anaemia and its predictors among young women (15–24 years) in low- and middle-income countries: A setback to SDG progress. *BMC Public Health, 23*(1), Article 1292. https://doi.org/10.1186/s12889-023-16187-5

Mubarok, F. H., & Nurkhasanah. (2022). Minuman fungsional milkshake daun ubi jalar ungu, kedelai, dan angkak sebagai

diet dislipidemia. *Pharmaceutical Journal of Indonesia, 19*(2), 282–293.

Mushollini, F., Salimo, H., & Kartikasari, L. R. (2024). Cookies of purple sweet potato and tempeh flour as functional foods: Nutritional value and sensory acceptability. *Food Research, 8*(Suppl. 2), 50–54. https://doi.org/10.26656/fr.2017.8(S2).53

Nguyen, H. C., Chen, C.-C., Lin, K.-H., Chao, P.-Y., & Lin, H.-H. (2021). Bioactive compounds, antioxidants, and health benefits of sweet potato leaves. *Molecules, 26*(7), Article 1820. https://doi.org/10.3390/molecules26071820

Nurlia, R., Syam, A., Zulkifli, A., Dirpan, A., Sumarmi, S., Naping, H., Balqis, B., & Salam, A. (2025). A quasi-experimental study on fortified tempeh: A nutritional intervention for fetal growth in Indonesia. *Asia Pacific Journal of Clinical Nutrition, 34*(5), 829–838. https://doi.org/10.6133/apjcn.202510_34(5).0011

Ogori, A. F., Julius, A., Tretyak, L., Kenijz, N., Mikolaychik, I., Morozova, L., Hleba, L., & Shariati, M. A. (2021). Effect of soymilk substitution on the quality properties of malted maize beverage drink. *Journal of Microbiology, Biotechnology and Food Sciences, 11*(2), e4844. https://doi.org/10.15414/jmbfs.4844

Omoba, O. S., Oyewole, G. O., & Oloniyo, R. O. (2020). Chemical compositions and antioxidant properties of orange-fleshed sweet potato leaves and consumer acceptability in vegetable soup. *Preventive Nutrition and Food Science, 25*(3), 293–300. https://doi.org/10.3746/pnf.2020.25.3.293

Pakpahan, S., Simbolon, G. A. H., & Nadeak, T. A. U. (2025). Organoleptic and hedonic tests of biscuits made from sweet potato leaves and tilapia fish. *Jurnal Penelitian Pendidikan IPA, 11*(4), 20–31. https://doi.org/10.29303/jppipa.v11i4.10641

Pibriyanti, K., Nufus, T., & Luthfiya, L. (2021). The relationship of menstrual cycle, menstrual length, frequency of menstruation, and physical activities with the incidence of anemia among adolescent girls at an Islamic boarding school. *Journal of Nutrition College, 10*(2), 112–119. https://doi.org/10.14710/jnc.v10i2.29855

Piskin, E., Cianciosi, D., Gulec, S., Tomas, M., & Capanoglu, E. (2022). Iron absorption: Factors, limitations, and improvement methods. *ACS Omega, 7*(24), 20441–20456. https://doi.org/10.1021/acsomega.2c01833

Ranteallo, Y., Ahmad, M., Syam, A., & Nilawati, A. (2023). Identification and quantification of minerals and vitamins in purple sweet potato (*Ipomoea batatas*) leaves. *IOP Conference Series: Earth and Environmental Science, 1230*(1), Article 012134. https://doi.org/10.1088/1755-1315/1230/1/012134

Samson, K. L. I., Fischer, J. A. J., & Roche, M. L. (2022). Iron status, anemia, and iron interventions and their associations with cognitive and academic performance in adolescents: A systematic review. *Nutrients, 14*(1), Article 224. https://doi.org/10.3390/nu14010224

Sari, N. W., Djokosujono, K., Utari, D. M., & Rohayati, N. (2022). Availability of sugar-sweetened beverages at home as the dominant factor related to consumption among students of SMAN 47 Jakarta, Indonesia. *Indonesian Journal of Public Health Nutrition, 3*(1), 32–42. https://doi.org/10.7454/ijphn.v3i1.6176

Setiawan, B., Aulia, S. S., Sinaga, T., & Sulaeman, A. (2021). Nutritional content and characteristics of pumpkin cream soup with tempeh addition as supplementary food for older adults. *International Journal of Food Science, 2021*, Article 6976357. https://doi.org/10.1155/2021/6976357

Shafiee, S. M., Amiri, F., Yousefi, F., & Nasab, N. A. (2024). Pro-oxidant/antioxidant balance correlates with red blood cell indices and anemia severity in anemic patients. *Reports of Biochemistry and Molecular Biology, 12*(4), 610–618.

Soni, R., Verma, D., Chopra, R., Singh, V., & Goswami, D. (2025). Demystifying intricate factors of nutritional anemia beyond iron deficiency: A narrative review. *Clinical Nutrition ESPEN, 69*, 745–764. https://doi.org/10.1016/j.clnesp.2025.08.034

Suárez, S., Mu, T., Sun, H., & Añón, M. C. (2020). Antioxidant activity, nutritional, and phenolic composition of sweet potato leaves as affected by harvesting period. *International Journal of Food Properties, 23*(1), 178–188. https://doi.org/10.1080/10942912.2020.1716796

Tan, Z. J., Abu Bakar, M. F., Lim, S. Y., & Sutimin, H. (2024). Nutritional composition and sensory evaluation of tempeh from different combinations of beans. *Food Research, 8*(2), 138–146. https://doi.org/10.26656/fr.2017.8(2).088

Wahyu, T. W., Krisnasary, A., & Yulianti, R. (2023). Anemia among adolescent girls: Its association with protein and iron intake. *Media Gizi Indonesia, 18*(1, Special Issue), 14–20. https://doi.org/10.20473/mgi.v18i1SP

Windardi, I. P., & Dewi, A. P. (2025). Pengaruh penambahan gula merah terhadap karakteristik hedonik dan mutu hedonik minuman fungsional sari daun ubi jalar. *Jurnal ILKES (Jurnal Ilmu Kesehatan), 16*(1), 141–145.

World Health Organization. (2023). *Global nutrition targets 2030: Anaemia brief*. World Health Organization.

Wu, J. Y., Wee, S., Ler, S. G., Henry, C. J., & Gunaratne, J. (2025). Unraveling the impact of tempeh fermentation on protein nutrients: An in vitro proteomics and peptidomics approach. *Food Chemistry, 474*, Article 143154. https://doi.org/10.1016/j.foodchem.2025.143154

Wu, Q., Wang, Z., Xia, J., Xu, H., Huang, G., Feng, G., & Gou, X. (2025). Association between composite dietary antioxidant indices and anemia: NHANES 2003–2018. *PLOS ONE, 20*(1), e0316397. https://doi.org/10.1371/journal.pone.0316397

Ye, J.-H., Ye, Y., Yin, J.-F., Jin, J., Liang, Y.-R., Liu, R.-Y., Tang, P., & Xu, Y.-Q. (2022). Bitterness and astringency of tea leaves and products: Formation mechanism and reducing strategies. *Trends in Food Science & Technology, 123*, 1–14. https://doi.org/10.1016/j.tifs.2022.02.031

Yuliani, S., Juniawati, Ratnaningsih, & Suryana, E. (2022). Characteristics of tempeh prepared from several varieties of Indonesian soybeans: Correlations between soybean size and tempeh quality properties. *IOP Conference Series: Earth and Environmental Science, 1024*(1), Article 012051. https://doi.org/10.1088/1755-1315/1024/1/012051