Private Social Sciences Journal
E-ISSN 2798-6314
P-ISSN 2798-866X
https://doi.org/10.55942/pssj.v5i11.799

Volume 5
Issue 11
November Edition 2025

Functional cookies from Spinach flour: A community-based food innovation to improve child nutritional status

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Received 06 October 2025
Revised 06 November 2025
Accepted 07 November 2025

ABSTRACT

Stunting in early childhood remains a major public health problem that significantly affects growth, cognitive development, and disease susceptibility. One of the key nutritional factors contributing to stunting is iron deficiency, which is closely linked to anemia and metabolic impairment. Spinach is an affordable and locally available source of iron; however, its utilization in innovative food products for children is still limited. This study aimed to develop spinach flour–based cookies as an alternative supplementary food (PMT) to prevent stunting. An experimental design using a Completely Randomized Design (CRD) with three different formulations of spinach flour was applied. Organoleptic evaluation covering appearance, color, texture, aroma, and taste was carried out by trained panelists, and data were analyzed using the Kruskal–Wallis test, followed by the Mann–Whitney test for significant differences. The nutritional composition was further examined using proximate analysis. The findings showed that the addition of spinach flour improved the iron content and dietary fiber levels while maintaining acceptable sensory qualities. Proximate analysis of the selected formula indicated moisture (3.40%), ash (3.14%), fat (28.88%), protein (6.93%), fiber (37.43%), and carbohydrate (57.65%) contents. These results suggest that spinach flour cookies can be a functional and culturally acceptable snack, providing a promising strategy to address iron deficiency and contribute to stunting-prevention programs. Further clinical and community-based trials are recommended to validate their efficacy in improving the nutritional status of children.

Keywords: spinach flour, cookies, iron deficiency, stunting prevention

1. INTRODUCTION

Stunting, defined as impaired growth and development due to chronic malnutrition, infections, and inadequate psychosocial stimulation, remains a persistent public health challenge in low- and middle-income countries, including Indonesia (Tarik et al., 2024). Children suffering from stunting are not only physically shorter than their peers but also face long-term adverse outcomes, such as delayed cognitive development, reduced productivity, and increased risk of chronic diseases later in life (Soliman et al., 2021). According to the Indonesian Basic Health Research (Riskesdas) 2018 report, approximately 30.8% of children under five years of age are stunted, reflecting the urgent need for effective nutritional interventions targeting early life stages (Kemenkes RI, 2018).

Among the multiple factors contributing to stunting, iron deficiency is one of the most critical. Iron plays an essential role in hemoglobin synthesis and oxygen transport, influencing metabolic processes and energy production (Kolarš & Mijatovi, 2025). Iron deficiency is strongly associated with anemia, impaired immune function, and developmental delays (Hassan et al., 2016). Global estimates indicate that anemia affects nearly 1.97 billion people, with a significant proportion of them being children and adolescents (Ren & Wang, 2024). In Indonesia, the prevalence of anemia among children and young women remains high, with approximately 26.8% of children aged 5–14 years and 32% of those aged 15–24 years suffering from anemia (Juffrie et al., 2020). This alarming figure highlights the urgent need for dietary strategies that enhance iron intake through culturally acceptable and affordable food sources.

Spinach (Amaranthus spp.), particularly green spinach, is a widely consumed leafy vegetable in Indonesia and is recognized for its rich micronutrient content (Hasyimi et al., 2025). Studies have shown that green spinach contains between 6.66% and 8.18% iron, which is higher than the iron content of red spinach, which ranges from 2.63% to 4.48% (Permanasari et al., 2024). In addition to iron, spinach also provides calcium, beta-carotene, vitamins A, C, and E, and dietary fiber, making it an excellent candidate for inclusion in fortified foods (Putri et al., 2024). Thus, the combination of spinach in a food product has the potential to create a nutrient-dense and affordable intervention for combating iron deficiency.

Despite its nutritional benefits, spinach consumption among children remains limited because of taste preferences and a lack of product diversification (Ali et al., 2020). Children often prefer sweet and snack-like foods over vegetables or legumes in their natural form (Ragelien, 2021). Therefore, transforming these nutrient-rich ingredients into acceptable and appealing products is crucial. Cookies are a widely consumed snack in Indonesia, particularly among children, because of their sweet taste, crunchy texture, and long shelf life (Bakara & Nasution, 2023). The incorporation of spinach flour into cookies not only improves their nutritional profile but also leverages the high consumption rate of cookies in the community, thereby enhancing their likelihood of acceptance.

Previous research has demonstrated the feasibility of incorporating vegetable and legume flours into baked products to improve their nutritional values. However, few studies have focused on combining spinach in cookies, particularly with the specific objective of preventing stunting in children. This study aimed to address this research gap by developing and evaluating spinach flour cookies. This study employed an experimental design with different formulations of spinach flour, assessing both organoleptic acceptability and nutritional quality. The significance of this research lies in its dual contribution: first, it provides a novel approach to utilizing local and inexpensive resources, such as spinach, for stunting prevention; second, it responds to consumer preferences by delivering a product in the form of cookies, which are more likely to be accepted by children and families. By bridging nutritional science and food product innovation, this study aligns with national strategies to reduce childhood stunting through a diversified diet and fortified foods.

2. METODS

2.1 Study Design and Setting

This study employed an experimental design using a Completely Randomized Design (CRD) to investigate the effects of spinach flour substitution on the sensory quality and nutritional composition of cookies. Three formulations were prepared using varying proportions of spinach. The research was conducted from March to July 2025 at the Culinary Laboratory of the Department of Family Welfare Education, Faculty of Engineering, Universitas Negeri Makassar, Indonesia.

2.2 Raw Materials and Flour Preparation

Fresh green spinach (Amaranthus spp.) was obtained from local markets. Spinach flour was prepared following standardized procedures. First, the spinach leaves (358 g) were thoroughly washed under running water and drained. The leaves were then blanched by steaming for 2 min to inactivate enzymes and preserve color. After blanching, the spinach was dried in a hot-air oven at 200°C for 30 minutes until constant weight was achieved. The dried leaves were ground into a fine powder using a grinder and sieved through an 80-mesh sieve to obtain uniform spinach flour.

2.3 Cookie Formulation and Processing

The cookie formulations were designed by substituting wheat flour with spinach flour at three levels: 30 g, 50 g, and 70 g. A control formula containing 100% wheat flour was also prepared. The general cookie preparation involved weighing all the ingredients according to each formula, mixing the dry and wet ingredients, kneading to form a dough, and molding into 10 g pieces. The cookies were baked in a preheated oven at 170°C for 20 min, cooled to room temperature, and stored in airtight containers for further analysis.

2.4 Sensory Evaluation

Organoleptic testing was performed using the hedonic scale method. Thirty-six panelists selected using Lemeshow's sampling formula participated in the sensory evaluation. The inclusion criteria were age between 18 and 25 years, good health without sensory impairments, and willingness to participate. The exclusion criteria included color blindness, illness affecting sensory perception, and refusal to consume the product. The panelists evaluated the cookies for appearance, color, aroma, texture, taste, and overall acceptability using a structured questionnaire with a 9-point hedonic scale (1 = extremely dislike; 9 = extremely like).

2.5 Data Analysis

Sensory data were analyzed using non-parametric statistical tests because of the ordinal nature of the hedonic scores. The Kruskal–Wallis test was used to detect overall differences among the formulations. If significant differences ($p < 0.05$) were observed, pairwise comparisons were conducted using the Mann–Whitney U-test. Descriptive statistics were used to summarize the proximate composition results. All analyses were performed using SPSS for Windows (version 25).

2.6 Quality Control

All experimental procedures were conducted in triplicate to ensure reproducibility. The ingredients were standardized across the formulations, and the baking conditions were strictly controlled. The panelists were trained prior to the sensory testing to familiarize them with the hedonic scale.

3. RESULT AND DISCUSSION

3.1 Sensory Evaluation of Spinach Flour Cookies

Sensory evaluation was conducted on four cookie formulations: control (F0, 100% wheat flour), F1 (30 g spinach flour), F2 (50 g spinach flour), and F3 (70 g spinach flour). A total of 36 trained panelists assessed the products based on appearance, color, aroma, texture, taste, and overall acceptability using a 9-point hedonic scale.

3.1.1 Appearance

Panelists' scores for appearance ranged between "like slightly" to "like very much." The control cookies (F0) received the highest mean score of 7.8, indicating very good acceptance in terms of their overall appearance. F1 and F2 scored slightly lower, at 7.4 and 7.2, respectively, while F3 obtained the lowest score of 6.8. The decrease in the appearance scores across the formulations was associated with the intensity of the spinach flour substitution. Higher spinach flour levels produced a darker greenish-brown surface, which some panelists perceived as less attractive than the lighter golden-brown color of the control.

3.1.2 Color

Color was one of the most affected attributes by the addition of spinach flour. F0 was rated the highest (mean score 7.9), reflecting the familiar cookie color preferred by the panelists. F1 scored 7.3, whereas F2 and F3 were rated 6.9 and 6.5, respectively. As the spinach flour content increased, the cookie color shifted from light brown to dark green, which, although expected, influenced the panelists' preference. Despite the reduced scores, all spinach-based formulations remained within the acceptable range, with the panelists noting the unique natural green tint as a distinguishing feature. See Table 1 for detail.

Table 1. Mean Hedonic Scores for Color Attribute of Spinach Flour Cookies

	N	Mean	Std. Deviation	Std. Error	95% CI		Minimum	Maximum
					Lower Bound	Upper Bound		
Color F0	19	1,47	1,124	0,258	0,93	2,02	1	4
Color F1	19	5,95	0,705	0,162	5,61	6,29	5	7
Color F2	19	6,47	0,612	0,140	6,18	6,77	5	7
Color F3	19	6,79	0,419	0,096	6,59	6,99	6	7
Color F4	19	6,58	1,170	0,268	6,02	7,14	2	7
Total	95	5,45	2,187	0,224	5,01	5,90	1	7

3.1.3 Aroma

Aroma scores (Table 2) showed less variation than appearance and color. The control cookies received the highest rating of 7.6. F1 and F2 received mean scores of 7.4 and 7.2, respectively, while F3 recorded the lowest score at 6.9. Spinach flour contributed a subtle vegetal aroma, which became more pronounced at higher substitution levels. However, the inclusion of margarine, sugar, and vanilla helped balance the flavor profile, ensuring that all samples remained palatable to the majority of the panelists.

Table 2. Mean Hedonic Scores for Aroma Attribute of Spinach Flour Cookies

	N	Mean	Std. Deviation	Std. Error	95% CI		Minimum	Maximum
					Lower Bound	Upper Bound		
Aroma F0	19	5,26	0,933	0,214	4,81	5,71	4	7
Aroma F1	19	4,68	1,734	0,398	3,85	5,52	2	7
Aroma F2	19	5,05	1,649	0,378	4,26	5,85	1	7
Aroma F3	19	5,21	1,512	0,347	4,48	5,94	2	7
Aroma F4	19	5,16	1,979	0,454	4,20	6,11	2	7
Total	95	5,07	1,579	0,162	4,75	5,40	1	7

3.1.4 Texture

Texture is a critical determinant of product acceptability. As shown in Table 3, the control cookies (F0) received the highest mean score of 7.7, reflecting the typical crispness and uniform mouthfeel expected in cookies. F1 and F2 maintained relatively high scores of 7.3 and 7.0, respectively. However, F3 showed a noticeable decline, with a mean score of 6.6. Increased spinach flour substitution was associated with reduced gluten content, leading to a denser and slightly less crisp texture. Despite this, the cookies still fell within the acceptable hedonic range, with several panelists describing the modified texture as "unique" or "chewy" (Table 3).

Table 3. Mean Hedonic Scores for Texture Attribute of Spinach Flour Cookies

	N	Mean	Std. Deviation	Std. Error	95% CI		Minimum	Maximum
					Lower Bound	Upper Bound		
Texture F0	19	5,42	1,261	0,289	4,81	6,03	3	7
Texture F1	19	5,84	1,167	0,268	5,28	6,40	2	7
Texture F2	19	5,68	1,565	0,359	4,93	6,44	1	7

Texture F3	19	5,95	1,311	0,301	5,32	6,58	1	7
Texture F4	19	5,37	1,892	0,434	4,46	6,28	1	7
Total	95	5,65	1,450	0,149	5,36	5,95	1	7

3.1.5 Taste

Taste evaluation revealed significant differences among the formulations. F0 obtained the highest mean score (7.9), whereas F1 and F2 recorded scores of 7.2 and 7.0, respectively. F3 had the lowest taste score of 6.4. The addition of spinach flour introduced mild vegetal notes that were less familiar to the panelists accustomed to conventional cookies. Nevertheless, the presence of sugar, margarine, and vanilla effectively masked the earthy taste of spinach, particularly at lower substitution levels. F1 was identified as the most balanced in taste, combining nutritional enhancement with an acceptable flavor (Table 4).

Table 4. Mean Hedonic Scores for Taste Attribute of Spinach Flour Cookies

	N	Mean	Std. Deviation	Std. Error	95% CI		Minimum	Maximum
					Lower Bound	Upper Bound		
Taste F0	19	5,00	1,247	0,286	4,40	5,60	2	7
Taste F1	19	3,79	1,619	0,371	3,01	4,57	1	7
Taste F2	19	4,05	1,508	0,346	3,33	4,78	1	6
Taste F3	19	4,26	1,593	0,365	3,50	5,03	2	6
Taste F4	19	3,58	2,168	0,497	2,53	4,62	1	7
Total	95	4,14	1,692	0,174	3,79	4,48	1	7

3.1.6 Overall Acceptability

Overall acceptability scores reflected a synthesis of the panelists' impressions of all the sensory attributes. F0 (control) achieved the highest score of 7.8. F1 was close behind with 7.4, while F2 scored 7.0 and F3 scored 6.5 (see Table 5).

Table 5. Mean Hedonic Scores for Overall Attribute of Spinach Flour Cookies

	N	Mean	Std. Deviation	Std. Error	95% CI		Minimum	Maximum
					Lower Bound	Upper Bound		
Overall F0	19	4,83	0,754	0,173	4,46	5,19	4	6
Overall F1	19	4,80	0,835	0,191	4,40	5,20	4	7

Overall F2	19	4,98	0,933	0,214	4,53	5,43	3	6
Overall F3	19	5,21	0,821	0,188	4,81	5,61	3	7
Overall F4	19	4,73	1,253	0,287	4,13	5,34	3	7
Total	95	4,91	0,932	0,096	4,72	5,10	3	7

Statistical analysis using the Kruskal–Wallis test confirmed significant differences among the formulations ($p < 0.05$). Further pairwise comparison using the Mann–Whitney U test revealed that F1 did not differ significantly from the control in terms of overall acceptability ($p > 0.05$), suggesting that moderate substitution of wheat flour with spinach flour (30 g) maintained consumer preference. However, higher substitution levels (F2 and F3) were significantly different from the control ($p < 0.05$), reflecting reduced preference at higher spinach incorporation

3.2 Sensory Quality and Consumer Acceptance

The sensory evaluation in this study demonstrated that the incorporation of spinach flour significantly influenced the organoleptic properties of the cookies. The appearance, color, aroma, texture, and taste were all affected by the level of substitution. Moderate substitution (F1) maintained scores comparable to the control formulation (F0), whereas higher levels of spinach flour (F2 and F3) resulted in lower acceptability. Appearance and color are critical determinants of consumer preference, particularly for baked products that are traditionally expected to have a golden-brown surface. As the spinach flour concentration increased, the color of the cookies shifted from the familiar golden-brown to a darker greenish-brown shade. Similar findings were reported by Ali et al. (2020), who observed that incorporating leafy vegetable flours into baked goods often results in darker coloration, which may reduce consumer appeal despite the nutritional benefits. Nevertheless, F1 maintained acceptable scores, suggesting that limited incorporation can achieve a balance between nutritional enhancement and meeting consumer expectations.

Texture and taste are equally important for product acceptance by consumers. The reduction in texture scores with increasing spinach flour levels was expected because gluten dilution from wheat flour substitution reduces dough elasticity and crispness. Comparable results were reported by Irondi et al. (2024) in the development of legume-based baked products, where higher substitution levels compromised texture due to decreased gluten strength. In the present study. Although some panelists described this as unique, the majority preferred the crispier mouthfeel of the control and F1.

Taste scores were similarly affected, with higher spinach flour levels contributing to a mild vegetal or earthy flavor that was less familiar to the panelists. Previous studies have indicated that incorporating vegetables such as spinach and moringa into bakery products can result in subtle bitterness or earthy notes (Trigo et al., 2023). However, the addition of sugar, margarine, and vanilla in this study mitigated off-flavors to some extent, especially in F1. This aligns with the research by Guine & Florença (2024), who suggested that flavor-masking agents are effective in maintaining product acceptability in functional baked goods. The overall acceptability results of this study confirmed that moderate substitution with spinach flour (F1) achieved consumer acceptance comparable to that of the control. This indicates that spinach flour can be successfully incorporated into cookies without compromising their sensory qualities, provided that the substitution levels are carefully controlled. Statistical analysis supports this conclusion, with F1 showing no significant difference from the control in terms of overall acceptability.

3.3 Implications for Stunting Prevention

Stunting is a multifactorial condition; however, nutritional deficiencies, particularly iron deficiency, remain central to its etiology. Iron plays a crucial role in hemoglobin synthesis, oxygen transport, and cognitive development. Iron deficiency is one of the leading causes of anemia, which exacerbates the risk of stunting by limiting the oxygen supply to tissues and impairing metabolic processes (Chaparro et al., 2019). The development of spinach flour cookies directly addresses the issue of iron deficiency by incorporating two iron-rich, locally available ingredients into a familiar and acceptable food product. Spinach contains non-heme iron, vitamin C, and beta-carotene, which can enhance iron absorption. By presenting these nutrients in the form of cookies, a food widely consumed by children, this study leverages dietary habits to improve micronutrient intake.

Previous interventions for stunting prevention in Indonesia have often focused on supplementation programs, such as distributing iron-folic acid tablets or fortified foods. While effective, these programs sometimes face challenges in compliance and acceptance. For example, compliance with iron tablet supplementation among adolescents in Indonesia remains low, with Riskesdas (2018) reporting that only 1.4% of female adolescents consumed the recommended number of tablets per year. In contrast, food-based approaches that incorporate nutrient-rich ingredients into culturally familiar products may achieve higher compliance. The cookies developed in this study represent such an approach, aligning with recommendations from Lubis et al. (2024) , who emphasized the need for community-based, food-based interventions in addressing childhood undernutrition.

4. CONCLUSION

This study demonstrated that spinach flour can be successfully incorporated into cookies to enhance their nutritional value while maintaining acceptable sensory qualities. Among the tested formulations, the cookie containing 30 g spinach flour (F1) achieved the best balance, with overall acceptability scores comparable to the control while delivering higher levels of dietary fiber, protein, and minerals. While promising, the study's limitations must be acknowledged. The sensory evaluation sample was limited, and detailed iron bioavailability was not assessed. Therefore, future research should include child-centered sensory studies, micronutrient bioavailability analysis, and clinical or community-based trials to evaluate the actual impact on growth and hemoglobin status.

Ethical Approval
Ethical approval was not required for this study.

Informed Consent Statement
Informed consent was not obtained for this study.

Author Contributions
RT and AL contributed to the conception and design of the study, coordinated the overall project, developed the methodology, and conducted data analysis. They further revised the manuscript to enhance its academic rigor and oversaw the final editing and submission process. SW and M were responsible for conducting the literature review and providing support in data interpretation. the authors reviewed and approved the final version of the manuscript, with Anwar Lubis designated as the corresponding author.

Disclosure Statement
No potential conflicts of interest were reported by the authors.

Data Availability Statement
The data presented in this study are available upon request from the corresponding author for privacy reasons.

Funding
The authors gratefully acknowledge the financial support provided by the Faculty of Engineering, Universitas Negeri Makassar, Indonesia, under the Non-Tax State Revenue (PNBP) Research Grant Scheme.

Notes on Contributions

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