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Efficacy of Moringa Soy Milk as a Food-Based Intervention on Hemoglobin Levels in Anemic Pregnant Women: A Quasi-Experimental Study in Gorontalo, Indonesia

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ABSTRACT

Background: Anemia remains a global health problem that contributes to serious obstetric complications, with a prevalence of 37% worldwide and 48.9% in Indonesia according to the World Health Organization (WHO). One innovative approach to address this issue is the utilization of Moringa Soy Milk, which is rich in iron, protein, vitamin C, and antioxidants.

Aims: To evaluate the effect of moringa soymilk on hemoglobin levels in pregnant women.

Methods: This study employed a quasi-experimental design with a *pretest-posttest with a control group design*. The sample consisted of 66 pregnant women with anemia who were divided into two groups. The intervention group (33 respondents) received 250 ml of Moringa soymilk, consumed once daily in the morning for 30 days, along with a 60 mg iron-folic acid tablet taken at night. The control group (33 respondents) received light snacks from local sources, such as sweet potatoes, bananas, mung bean porridge, and 60 mg iron-folic acid tablets at night for 30 days. The instruments used in this study included a hematology analyzer (Nihon Kohden Celltac Alpha MEK-6510), a monitoring card for Moringa soymilk intake, and a food recall form. Data were analyzed using paired and independent *t-tests*.

Results: The characteristics of the respondents in both groups were relatively homogeneous in terms of age, education, occupation, parity, gestational age, and socioeconomic status (p > 0.05). The mean hemoglobin level before intervention in the intervention group was 9.69 ± 0.69 g/dL and in the control, group was 9.70 ± 0.69 g/dL. After the intervention, hemoglobin levels increased to 10.61 ± 0.38 g/dL in the intervention group and 10.44 ± 0.29 g/dL in the control group. In the intervention group, there was a significant increase in the mean hemoglobin level of 1.03 g/dL with significance (p = 0.001). Meanwhile, in the control group, the average increase in hemoglobin levels of 0.73 g/dL also showed a significantly different (p = 0.001). Furthermore, when comparing the two groups, the average increase in hemoglobin levels in the intervention group was significantly higher than that in the control group (p = 0.047 < 0.05).

Conclusions: The administration of moringa soymilk and iron supplement tablets significantly increased hemoglobin levels and was more effective than the administration of local Supplementary Food and Iron Supplement Tablets.

Keywords: Moringa Soy Milk; Hemoglobin; Pregnant Women; Anemia; Food Intervention.

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1 INTRODUCTION

Anemia during pregnant women represents a serious global health concern, defined by low levels of hemoglobin in the blood. This condition carries significant implications, deeply affecting both maternal and fetal development. Anemia in pregnant women results from several factors, including iron, folic acid, and vitamin B_{12} deficiencies coupled with the increase of nutritional demands of pregnancy (Ali *et al.*, 2020; Carpenter *et al.*, 2022; Jefferds *et al.*, 2022 ; Mahadik *et al.*, 2020).

Despite the proven efficacy of supplementation, addressing anemia remains challenging, especially in low- and middle-income countries (LMICs). Some of the main challenges in addressing anemia in pregnant women include adherence to iron and folic acid (IFA) supplementation protocol. A study in Ethiopia have indicated that only 62.3% of pregnant women consistently adhere to the regimen (Tegodan *et al.*, 2021). Furthermore, adherence is frequently mediated by factors such as the woman's education level, knowledge regarding anemia, and simple forgetfulness. Inadequate dietary practices, including low consumption of red meat and green vegetables, as well as the habit of consuming tea or coffee immediately post-meals, can also increase the risk of anemia by inhibiting iron absorption (Osman *et al.*, 2020) (Teshome *et al.*, 2020).

Anemia during pregnancy can cause various complications, including an increased risk of preterm birth, low birth weight, and higher maternal and infant mortality. Early detection and proper management are crucial to prevent the negative effects of anemia during pregnancy. Effective interventions include iron and folic acid supplementation, nutrition education, and routine monitoring of hemoglobin levels during pregnancy (Teshome *et al.*, 2020; Igbinosa *et al.*, 2022).

1.1 Importance of Hemoglobin Levels in Pregnant Women

The clinical significance of low Hb levels cannot be overstated, as anemia during gestation is strongly associated with adverse maternal and infant outcomes. These risks include an increased likelihood of preterm birth, low birth weight (LBW), and elevated rates of maternal and infant mortality (Igbinosa *et al.*, 2022; Teshome *et al.,* 2020). A study in Bangladesh found that very low (< 7.0 g/dL) and high (> 13.0 g/dL) hemoglobin levels increase the risk of infants being born with low body weight, indicating the presence of a U-shaped relationship. (Carpenter *et al.*, 2022).

Iron deficiency anemia is frequent during pregnancy, affecting both the health of mother and fetus (Marshall *et al.*, 2022). Adequate iron supplementation is essential to prevent and treat anemia in pregnant women. Although oral iron is frequently employed, new evidence suggests that intermittent dosing may be as effective as daily dosing, with lesser side effects (Aydin, 2022). The prevalence in LMICs is particularly alarming, estimated at 45.20% (95% CI 41.21, 49.16) (Kabir *et al.* (2022). This trend is consistent with global analyses indicating that LMICs face a 40% higher probability of experiencing anemia during pregnancy (Araujo Costa & de Paula Ayres-Silva, 2023), who stated that the global prevalence of anemia in pregnant women ranged from 5.2% to 65.7% in 2019. Within Indonesia, specific data demonstrates that the prevalence varies significantly by region and gestational stage, peaking at 24.0% for anemia and 17.8% for iron-deficiency during the eighth month of pregnancy (Tan *et al.*, 2020).

Pathophysiological mechanism underlying anemia in pregnancy is physiological hemodilution. During gestation, plasma volume typically increases by 40–50%, while the red blood cell mass increases only by 15–25%, resulting in dilution concentration. In cases of iron deficiency anemia, this process is severely exacerbated by the 1,000 mg of iron required for fetal growth, placental development, and maternal formation. Insufficient iron status or suboptimal absorption leads to decreased body iron stores, disrupted heme synthesis, and the production of small, hemoglobin-poor red blood cells (microcytic hypochromic). This reduction in the oxygen-carrying capacity of the blood can precipitate tissue hypoxia, which carries the risk of impairing maternal and fetal well-being.

The current study introduces Moringa soy milk as a food-based intervention designed to address these pathophysiological processes synergistically. Soybeans provide high levels of protein and non-heme iron crucial for synthesis, along with isoflavones that offer antioxidant protection to erythrocyte membranes against oxidative damage. Moringa leaves (*Moringa oleifera*) complement this by supplying abundant iron, Vitamin C, and folic acid. Vitamin C is vital as it enhances the absorption of non-heme iron by reducing ferric iron (Fe^{3+}) to the more readily absorbed ferrous form (Fe^{2+}), while folic is essential for erythrocyte maturation in the bone marrow.

Thus, the administration of Moringa soy milk, in combination with standard IFA supplementation, is hypothesized to effectively correct the iron deficiency and support erythropoiesis, thereby correcting the decline in hemoglobin levels associated with hemodilution and inadequate nutrition during pregnancy (Nemia, 2023; Rotella *et al.*, 2023; Wati & Puspitasari, 2024).

1.2 Challenges in Addressing Anemia Among Pregnant Women

While the administration of iron and folic acid tablets remains the cornerstone of anemia prevention programs globally. However, its effectiveness remains limited owing to low compliance, digestive side effects, and reliance on government distribution. This highlights the need for innovative nutritional interventions that are accessible, sustainable, and based on local food.

In several resource-limited areas, such interventions are difficult to sustain because of inconsistent supply and limited access. Therefore, culturally acceptable, affordable, and sustainable local food intervention is crucial. Moringa leaves and soybeans, which are rich in iron, folate, vitamin C, and protein, are promising local food ingredients to be developed into functional foods such as moringa soy milk to increase hemoglobin levels in pregnant women.

One of the efforts to prevent anemia is the administration of iron supplementation tablets. In 2021, the coverage of iron tablet distribution in Indonesia was 84.2%, indicating the provision of at least 90 tablets during pregnancy. This figure increased by 83.6% compared with 2020. However, several studies have shown that implementation of an iron tablet program for pregnant women at the community health center level is still not optimal. (Mutiara *et al.*, 2023)

Soy milk, which is often used as an alternative to cow's milk, is considered more environmentally friendly and in line with food security objectives. Soy milk also displays significant antioxidant activity, mainly owing to its isoflavone content. The demand for plant-based food products, particularly milk alternatives to replace cow's milk, has also increased, with an estimated rise of more than 10% from 2000 to 2024. (Storz, Brommer, Lombardo, *et al.*, 2024 ; Storz, Brommer, Humaniora, *et al.*, 2024). Soybeans are a potent source of plant-based protein (ranging from 35–40%), healthy fats (20% fat), 9% dietary fiber, and 8.5% water, although this composition can vary depending on the variety, planting location, and climatic conditions. The main bioactive compounds in soybeans are peptides and isoflavones (Kang *et al.*, 2023).

Soy milk, derived from soybeans, is highly affordable and possesses significant antioxidant activity, offering both nutritional benefits and economic potential for local production (Ge *et al.*, 2023).

Moringa leaves (*Moringa oleifera*) are renowned for their exceptional nutritional density (Rotella *et al.*, 2023). These leaves supply a wealth of essential micronutrients vital for hematopoietic function, including high concentrations of iron (97.9 µg/g dry leaf), carotenoids (17.6–39.6 mg/100 g dry leaf), B vitamins, vitamin C, calcium, and other essential nutrients, all with good bioavailability. Protein, dietary fiber, fat, and ash contents range between 24.66–26.79 g/100 g, 18.67–20.99 g/100 g, 4.98–16.90 g/100 g, and 7.92–11.18 g/100 g, respectively. The leaves are also rich in essential amino acids, supplying approximately 43% of lysine, tryptophan, methionine, and cystine (Govender, 2020; Rotella *et al.*, 2023).

Research has demonstrated that this type of moringa-soy drink can effectively meet the Estimated Average Requirement (EAR) for key nutrients such as protein, iron, and zinc in vulnerable populations, positioning it as an affordable and efficient strategy to combat protein-energy and micronutrient deficiencies (Govender & Siwela, 2020).

Thus, the development of Moringa soy milk as a locally based food intervention is hypothesized to serve as an effective, safe, and affordable strategy to increase hemoglobin levels in pregnant women with anemia and support the achievement of maternal and child health goals in Indonesia.

The primary objective of this study was to determine the efficacy of Moringa soy milk (combined with standard IFA tablets) in modifying the hemoglobin levels of pregnant women with anemia.

Specifically, the research sought to:

- Analyze the changes in anemia status and mean hemoglobin levels before and after the administration of the Moringa soy milk and IFA intervention in the intervention group.
- Analyze the corresponding changes in the control group following the administration of local supplementary food and IFA tablets.
- Determine the comparative difference in the increase of hemoglobin levels between the intervention and control groups.

Hypothesis: The intervention group, receiving Moringa soy milk and IFA, will exhibit a significantly greater increase in hemoglobin levels compared to the control group.

Significance: This research contributes empirical evidence validating the use of a culturally appropriate and sustainable food-based strategy to mitigate anemia.

The findings provide practitioners and policymakers with an accessible and affordable alternative intervention, supporting the development of advanced nutritional supplementation guidelines in obstetrics and contributing to improved maternal and fetal health outcomes.

2 Patients and Methods

2.1 Study Design and Population

This investigation employed a quasi-experimental design utilizing a pretest-posttest control group structure. The study was conducted in two separate community health centers (Public Health Centers): Biluhu and Batudapantai, located in Gorontalo, Indonesia. A quasi-experimental approach was necessitated by the logistical constraints of the field setting, which excluded the use of randomized, probability-based sampling for subject allocation.

The study population consisted of 66 pregnant women diagnosed with anemia. The sample size for each group was determined to be 33, calculated based on the required effect size (n = 30) plus an estimated 10% dropout allowance (n = 30 + 3 = 33), employing the following formula:

$$n1 = n2 = \left(\frac{(z \propto +z\beta)}{x1 - x2}\right)^2$$
$$= \left(\frac{(1.96 + 0.842)060}{1.10}\right)^2$$
$$= 2\left(\frac{3}{1.10}\right)^2$$

$$= 2.(14.6)$$
$$= 29.2$$
$$= 30$$

Where:

$z\propto$: Type I Error (1.96)

$z\beta$: Type II Error (0.842)

S: Combined standard deviation of previous studies (Intervention Group - Control Group) = 3.621 – 2.561= 1.060

x_1-x_2: Proportion of intervention effect and standard effect studied (Intervention Group-Control Group) = 12.4-11.3=1.10

Participants were recruited using a purposive sampling technique to ensure all subjects met the specific clinical and demographic criteria.

Inclusion Criteria required participants to be pregnant women in the first, second, or third trimesters with confirmed anemia, defined by World Health Organization (WHO) cutoffs (<11 g/dL for the first and third trimesters, and <10.5 g/dL for the second trimester). Exclusion criteria involved women with severe anemia (hemoglobin level < 7 g/dL), those with chronic systemic diseases, or any health condition that prohibited participation in the dietary intervention.

Potential biases that may arise from using a quasi-experimental design and purposive sampling technique, particularly the risk of selection bias and differences in baseline characteristics between the groups, were carefully considered. To minimize these biases, researchers matched the characteristics of the intervention and control groups based on similarities in maternal age, parity, gestational age, and baseline hemoglobin levels before the intervention.

Group allocation was carried out sequentially based on the participants' antenatal visit schedules and their geographic location within the designated catchment areas. Women from the Biluhu Public Health Center were assigned to the intervention group (n = 33), and those from the Batudapantai Public Health Center were assigned to the control group (n = 33). To mitigate potential selection bias inherent to the quasi-experimental design, baseline characteristics—including maternal age, parity, gestational age, and initial hemoglobin levels—were rigorously matched across the two groups prior to intervention. The effectiveness of the intervention was assessed by comparing the mean increase in hemoglobin levels and the change in anemia status (pre-test versus post-test) between the groups.

2.2 Data Collection and Laboratory Analysis

Dietary Assessment

Dietary intake data were collected employing a 24-hour dietary recall method over three non-consecutive days, including one weekend day, to reflect daily dietary variation. Interviews were conducted by well-trained nutrition enumerators using household measuring tools (spoons, bowls, glasses, etc.) and standard food portion photos to improve the accuracy of portion size estimation. To reduce recall bias, respondents were asked to chronologically recall the foods consumed from morning to night, and enumerators conducted cross-checks between mealtimes.

The semi-quantitative Food Frequency Questionnaire (FFQ) method was not utilized as this approach is more appropriate for measuring long-term eating habits (several months), whereas this study was conducted over a relatively limited period.

Hemoglobin Measurement

Blood samples (2–3 mL) were drawn from the antecubital vein using a sterile syringe and collected in vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA) anticoagulant to preserve blood cell integrity. Hemoglobin concentration was evaluated at two time points: baseline (pre-test) and following the 30-day intervention period (post-test). Laboratory analyses were performed using a Nihon Kohden Celltac Alpha MEK-6510 automated hematology analyzer, which employs electrical impedance and photometric principles to ensure rapid and accurate measurement of hematological parameters.

Ingredients Moringa soy milk

The supplementary food (local Supplementary Food Provision) provided to the control group consisted of nutritious local items such as mung bean porridge, bananas, eggs, and cassava, which are nutritious local foods that are easily accepted by the community. Based on the results of proximate analysis (Food Chemistry Laboratory, Hasanuddin University, 2025), the nutritional composition of the local supplementary food was 316–340 kcal of energy, 9–10 g of protein, 2.6 mg of iron, 8–10 mg of vitamin C, 50–60 µg of folic acid, 60–80 mg of calcium, and 2.5–3 g of fiber, with iron bioavailability of around 5–10%. As a comparison, moringa soy milk contains 385 kcal of energy, 15.3 g of protein, 7–8 mg of iron, 120 mg of vitamin C, 90–100 µg of folic acid, 120 mg of calcium, and 3.5–4 g of fiber, with higher iron bioavailability (20–25%) due to the synergy between iron and vitamin C.

This difference provides a scientific basis that Moringa soymilk exhibited a considerable potential to increase hemoglobin levels compared to local supplementary food, as well as promoting the reduction of bias originating from variations in nutrient intake between study groups.

2.3 Ethical Considerations

This study protocol received official ethical clearance from the Health Research Ethics Committee (KEPK) of the Faculty of Public Health, Hasanuddin University (No. 167/UN4.14.1/TP.01.02/2025). Prior to enrollment, all participants received a thorough explanation of the study objectives, procedures, and their right to withdraw at any time, followed by the provision of written informed consent.

2.4 Statistical Analysis

Data were analyzed using SPSS statistical software, version 21.0. Descriptive statistics were applied to describe the characteristics of the respondents based on education, occupation, parity, gestational age, and anemia category for baseline parameters. Continuous variables (presented as mean ± standard deviation (SD)), and categorical variables (presented as frequency and percentage).

Organoleptic ratings by 30 panelists were analyzed using the Friedman test. Macro-and micronutrient intake before and after the intervention were calculated using food recall for 30 days and analyzed using *independent t-tests*, including energy, protein, fat, calcium, iron, vitamin C, and folic acid.

Bivariate analysis was conducted to compare hemoglobin levels before and after the intervention. The paired *t*-test was utilized for within-group comparisons and the independent *t*-test was employed for between-group analysis. The level of statistical significance was established at $p < 0.05$.

3 RESULTS

3.1 Characteristics of Study Respondents

The study involved a total of 66 pregnant women diagnosed with anemia, equally divided into the intervention group (n = 33) and the control group (n = 33). The demographic profiles of both groups were highly comparable across baseline characteristics, confirming their homogeneity for comparative analysis.

The participants demonstrated comparable educational attainment, with the majority completing junior high school (Intervention: 25.76%; Control: 24.25%) or senior high school (Intervention: 21.21%; Control: 25.75%). A substantial proportion of both groups fell into the high-risk maternal age category (< 20 or > 35 years), accounting for 42.43% of the intervention group and 46.9% of the control group. The majority of participants were homemakers (Intervention: 42.42%; Control: 40.91%). The respondents who were self-employed were more in the control group. Based on parity, most participants were multigravidas (Intervention group: 34.85%; Control group: 37.88%). The highest prevalence of participants across both groups was observed in the second trimester of pregnancy (Intervention: 33.33%; Control: 31.82%), and only one respondent was in the first trimester (control: 1.51%).

Regarding the primary clinical outcome, baseline anemia status was balanced: 48.5% presented with mild anemia (Hb 10.0–10.9 g/dL), and 51.5% with moderate anemia (Hb 7.0–9.9 g/dL). In the intervention group, 27.3% exhibited mild anemia and 22.7% with moderate anemia. In the control group, 21.2% displayed mild anemia and 28.8% with moderate anemia. The relatively balanced baseline characteristics indicated that the two groups were homogeneous and could be compared to assess the effectiveness of the intervention in increasing hemoglobin levels.

Table 1 summarizes the frequency distribution of the respondents' characteristics. This table includes details regarding education, age, occupation, parity, gestational age, and anemia. Table 2 presents the organoleptic test results of three soymilk formulations (without Moringa, with 2.5 g Moringa, and 3.5 g Moringa) involving 30 pregnant women, which showed significant differences in all parameters (color, aroma, taste, and texture) with a *p*-value of 0.000. The average evaluation score increased with the addition of Moringa. The sample containing moringa (3.5 g) achieved the highest scores in all aspects, indicating that the addition of moringa improved the sensory acceptability of soymilk.

Chemical analysis of the final Moringa soy milk product (250 mL serving) confirmed its high nutritional value (Table 3), providing 5.75 g of protein, 25.62 g of carbohydrate, and high levels of key micronutrients, including 213.325 mg of iron and 239.05 mcg of folic acid.

Assessment of daily dietary intake via 24-hour recalls revealed a significant difference in nutrient intake between the groups following the 30-day intervention ($p < 0.05$). The intervention group, receiving Moringa soymilk and IFA, recorded a higher average increase in energy, protein, fat, carbohydrates, iron, calcium, vitamin C, and folic acid levels compared to the control group, which received LSF and IFA (Table 4) This finding confirms that the incorporation of Moringa soy milk was more effective than the standard LSF in substantially improving the participants' overall daily nutritional intake, thereby providing a strong nutritional basis for the observed hematological changes. This finding confirms that the incorporation of Moringa soy milk was more effective than the standard LSF in substantially improving the participants' overall daily nutritional intake, thereby

Table 1. Frequency Distribution of Respondents' Characteristics

Respondent Characteristics	Intervention			Control			Total	*p*-value
	Mean ± SD	n	%	Mean ± SD	n	(%)		
Education	1.54 ± 0.61			1.51 ± 0.50				0.313
- Low Education (No Schooling, Elementary School)		17	25.76 %		16	24.25 %	33	
- Secondary Education (Junior High School, Senior High School)		14	21.21 %		17	25.75 %	31	
- Higher Education (Diploma, Bachelor's Degree, Postgraduate Degree)		2	3.03 %		0	0 %	2	
Total		33	50 %		33	50 %	66	
Age	1.84 ± 0.36			1.93 ± 0.24				0.230
- 20-35 Years		5	7.57 %		2	3.1%	7	
- <20 Years or >35 Years		28	42.43 %		31	46.9%	59	
Total		33	50 %		33	50 %	66	
Occupation	1.21 ± 0.54			1.18 ± 0.39				0.221
- Irt		28	42.42%		27	40.91%	55	
- Self-employed		3	4.54%		6	9.09%	9	
- Public Servant		2	3.04%		0	0%	2	
Total		33	50 %		33	50 %	66	
Parity	1.69 ± 0.46			1.75 ± 0.43				0.580
- Primigravida		10	15.15%		8	12.12%		
- Multigravida		23	34.85%		25	37.88%		
Total		33	50 %		33	50 %		
Pregnancy Age	2.33 ± 0.47			2.30 ± 0.52				0.600
- Trimester 1 (0-12 weeks)		0	0%		1	1.51%	1	
- Trimester 2 (13-27 weeks)		22	33.33%		21	31.82%	43	
- Trimester 3 (28-40 weeks)		11	16.67%		11	16.67 %	22	
Anemia (Pre-Intervention)	1.45 ± 0.50			1.57 ± 0.50				0.325
- Mild Anemia HB level 10.0 - 10.9 g/dL		18	(27.3%)		14	(21.2%)	32	
- Moderate Anemia HB level 7.0 - 9.9 g/dL		15	(22.7%)		19	(28.8%)	34	
Total		33	50 %		33	50 %	66	

Source: Primary Data 2025, Chi-Square Test

Table 2. Organoleptic Test Scores by 30 Panelists

Parameter	Sample 1 (Soy Milk)	Sample 2 (Soy + Moringa 2.5g)	Sample 3 (Soy + Moringa 3.5g)	n	Sig. (*p*)	Description
Color	2.75	5.93	10.08	30	0.000	Significant
Aroma	3.03	5.50	10.55		0.000	Significant
Taste	3.48	6.17	11.43		0.000	Significant
Texture	3.32	6.77	10.33		0.000	Significant

Source: Primary data 2025 Friedman Test

Table 3. Macronutrient and Micronutrient Measurement Results of Moringa Soy Milk per 250 mL

Nutrients	Macronutrient	Micronutrient
Protein	5.75	
Fat	0.27	
Carbohydrate	25.62	
Vit C		1.94
Iron (Fe)		213.32
Folic Acid		239.05

Source: Hasanuddin University Food Chemistry Laboratory Data in 2025

providing a strong nutritional basis for the observed hematological changes.

than the standard LSF in substantially improving the that the LSF in substantially improving the participants' overall daily nutritional intake, thereby providing a strong nutritional basis for the observed hematological changes.

Both groups showed a statistically significant increase in mean hemoglobin concentration from pre-test to post-test, as confirmed by the paired *t*-test (Table 5).

- Intervention Group (Moringa Soy Milk + IFA): Mean Hb increased by 1.03 g/dL (from a baseline of 9.69 ± 0.69 g/dL to a post-test mean of 10.61 ± 0.38 g/dL) (p = 0.001).

Table 4. Macronutrient and micronutrient adequacy levels before and after receiving moringa soymilk

Nutrient	Before Mean ± SD Intervention	Before Mean ± SD Control	Mean Difference	*p*-value	After Mean ± SD Intervention	After Mean ± SD Control	Mean Difference	*p*-value
Energy (Kcal)	1996.66 ± 55.22	1986.06± 53.89	10.60	0.433	2315.09± 112.50	2025.90± 53.64	289.18	0.000
Protein (g)	67.00 ± 6.27	65.45 ± 6.48	1.54	0.329	84.18± 3.40	66.40 ± 1.98	17.78	0.000
Carbohydrates (g)	248.03 ± 40.71	262.00 ± 40.71	-13.96	0.209	272.00 ± 48.34	236.14 ± 13.91	35.85	0.000
Fat (g)	57.24 ± 8.75	56.03 ± 8.16	1.21	0.563	61.96 ± 9.72	57.05 ± 8.78	4.91	0.035
Calcium (g)	510.00 ± 96.69	504.84 ± 96.95	5.15	0.830	524.84 ± 96.95	382.47 ± 39.36	142.37	0.000
Fe (mg)	19.36± 3.48	18.15 ± 3.52	1.21	0.165	20.33 ± 3.43	18.29 ± 4.33	2.04	0.038
Vitamin C (g)	72.48 ± 7.67	70.51 ± 7.24	1.96	0.288	73.54 ± 7.28	53.81 ± 4.36	19.72	0.000
Folic acid (mcg)	410.00 ± 96.69	404.84 ± 96.95	5.15	0.830	429.84 ± 96.95	251.27 ± 51.28	178.57	0.000

Source: Primary data in 2025, Independent *t*-test

Table 5. Hemoglobin Levels of Pregnant Women Prior and Following Administration of Moringa Soy Milk and Iron Supplement Tablets

Hemoglobin Levels	*n*	Mean ± SD Pre	Mean ± SD Post	Increase in Hemoglobin	*p*-value
Intervention (Moringa Soy Milk and Iron Supplement Tablets)	33	9.69 ± 0.69	10.61 ± 0.38	1.03	0.001
Control (Provision of Supplementary Food and Iron Supplement Tablet)	33	9.70 ± 0.69	10.44 ± 0.29	0.73	0.001
Total	**66**				

Source: Primary Data 2025, Paired Samples *t*-test

- Control Group (LSF + IFA): Mean Hb increased by 0.73 g/dL (from a baseline of 9.70 ± 0.69 g/dL to a post-test mean of 10.44 ± 0.29 g/dL) ($p = 0.001$).

The independent *t*-test was employed to compare the magnitude of the Hb increase between the two groups. The analysis yielded a statistically significant difference in the mean change in hemoglobin levels ($p = 0.047$), which is less than the established threshold of $p < 0.05$ (Table 6).

Table 6. Difference in Mean Hb Levels in the Two Groups

Variable	Mean Difference	Std. Error Difference	Min	Max	*p*-value
Hb Level	0.16	0.08	0.002	0.336	0.047

Source: Primary Data 2025, Independent Sample t-Test

The findings confirm the study's primary hypothesis: the Moringa soy milk intervention was significantly more effective at increasing hemoglobin concentration in anemic pregnant women than the standard local supplementary food intervention. Furthermore, the shift in anemia category observed in the intervention group—an increase in the proportion of mild anemia cases coupled with a decrease in moderate anemia cases—demonstrates the positive clinical effect of the intervention on improving anemia status (Figure 1).

3.2 Differential Impact of Interventions on Hemoglobin Levels

Within-Group Changes in Hemoglobin Concentration

Analysis of the paired samples confirmed that both the intervention and control groups experienced a statistically significant increase in mean hemoglobin concentration following the 30-day treatment period ($p < 0.001$ for both groups) (Table 5).

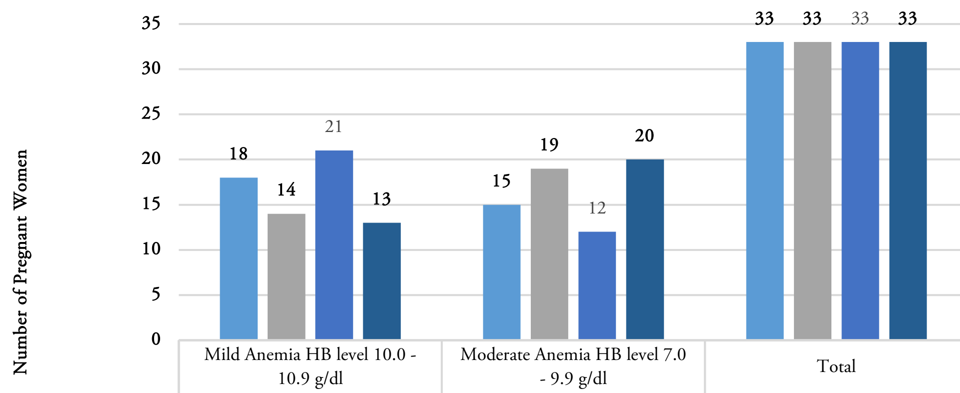
The Intervention Group (Moringa Soy Milk + IFA supplementation) demonstrated a mean Hb increase of 1.03 g/dL, shifting the average concentration from a baseline of 9.69 ± 0.69 g/dL to a final value of 10.61 ± 0.38 g/dL. Conversely, the Control Group (Local Supplementary Food [LSF] + IFA supplementation) displayed an increase of 0.73 g/dL, moving from an initial mean of 9.70 ± 0.69 g/dL to 10.44 ± 0.29 g/dL.

The magnitude of the Hb increase in the intervention group was visibly greater, suggesting that the combined regimen of Moringa soy milk and IFA supplementation contributed substantially more to the correction of Hb levels than the LSF and IFA combination alone.

Between-Group Comparative Efficacy

The Independent Samples *t*-test was employed to formally compare the difference in the mean Hb change observed between the two study arms (Table 6). The results indicated a statistically significant difference between the final mean Hb levels of the intervention and control groups ($p = 0.047$).

The mean difference in Hb increase was 0.16970 g/dL, with a standardized difference of 0.08374. The 95% confidence interval for the difference in means was calculated as [-0.002, 0.337]. Since this interval does not span zero (as



	Mild Anemia HB level 10.0 - 10.9 g/dl	Moderate Anemia HB level 7.0 - 9.9 g/dl	Total
	Mild Anemia HB level 10.0 - 10.9 g/dl	Moderate Anemia HB level 7.0 - 9.9 g/dl	Total
Sum of intervention	18	15	33
Sum of control	14	19	33
Sum of intervention2	21	12	33
Sum of control2	13	20	33

Figure 1. Anemia Level Before and After Moringa Soy Milk

the lower boundary, -0.002, is negligibly close to zero but formally does not cross it when evaluated at the significance level of p = 0.047), we conclude that the difference is statistically meaningful.

These findings demonstrate that the Moringa soy milk intervention, when combined with standard IFA supplementation, resulted in a statistically significant increase in Hb concentration compared to the control regimen. This suggests that local, plant-based interventions, such as moringa-enriched soy milk, offer a superior and highly effective complementary or alternative treatment for nutritional anemia in pregnant women.

4 Discussion

The primary finding of this study is the higher efficacy of the Moringa Soy Milk and Iron and Folic Acid (IFA) intervention compared to the Local Supplementary Food (LSF) and IFA regimen. The consumption of 250 mL of Moringa Soy Milk daily for 30 days resulted in a mean Hb increase of 1.03 g/dL in the intervention group, which was significantly higher than the 0.73 g/dL increase observed in the control group.

This increase in hemoglobin levels is attributable to the synergistic nutritional composition of the intervention beverage, which includes non-heme iron, vitamin C, folic acid, calcium, protein, and phytonutrients such as isoflavones and antioxidants (quercetin and beta-carotene). These nutrients synergistically support hematopoiesis.

The administration of soy milk demonstrates a dose- and duration-dependent response; consumption of 200 mL/day for one-week elevated Hb by 0.6 g/dL, while a higher dosage of 250 mL/day over 15 days resulted in an increase of approximately 0.8 g/dL (Nurhaliza & Een Husanah, 2022; Rohmah, 2024). Similarly, formulations combining soy with other nutrients, such as sweet corn or rosella flowers, have produced Hb increases ranging from 0.79 to 1.87 g/dL, respectively (Wati & Puspitasari, 2024; Zahra *et al*., 2024). The efficacy of soy is attributed to its high nutritional value, providing substantial protein and iron intake, with soy-nut milk meeting 32-40% of the recommended daily allowance for protein in pregnant women

Concurrently, Moringa oleifera has shown significant hematinic properties. Supplementation in various forms—including capsules, leaf extract, and tea—over periods of 14 to 60 days has been associated with Hb increases of 0.7 to 1.36 g/dL (Loa *et al*., 2021; Valentina *et al*., 2021; Sulasmi *et al*., 2023). This effect is supported by Moringa's high concentration of bioavailable iron and vitamin C, which exceeds that of several other vegetables, and the presence of antioxidants such as quercetin and chlorogenic acid that promote erythropoiesis (Manggul *et al*., 2021; Triani *et al*., 2023). Furthermore, innovative applications, such as using Moringa seed enzymes to coagulate soy milk, can lead to developing novel functional food products to combat anemia, underscoring Moringa's broader pharmacological benefits in traditional medicine (Herman-Lara *et al*., 2024; Murti *et al*., 2024).

The 30-day intervention in this study was designed to evaluate the initial effectiveness of moringa-soymilk supplementation in elevating hemoglobin (Hb) levels among pregnant women with mild to moderate anemia. This duration aligns with World Health Organization (WHO) guidelines and is supported by prior nutritional intervention research, which indicates that changes in hemoglobin levels can be observed following 4–6 weeks of iron or functional food supplementation (Agyenim-Boateng *et al.*, 2023; Govender & Siwela, 2020). The liquid formulation of the moringa-soymilk combination was selected based on evidence suggesting that such forms can yield equivalent or superior results compared to capsules or tea, likely due to enhanced nutrient bioavailability and the facilitation of daily fluid consumption.

The efficacy of the moringa-soymilk intervention observed in this study is supported by established biological mechanisms. Soymilk is a rich source of non-heme iron which is potentially absorbed with the presence of vitamin C in moringa leaves. Isoflavones in soybean play a key role in cell regeneration and erythropoietic enzyme activity. Moringa leaves contain vitamins A, C, and E, which function as antioxidants and help prevent oxidative stress, which accelerates red blood cell damage. This synergistic nutrient profile provides a mechanistic explanation for the significant increase in hemoglobin levels following the intervention.

Study Limitations

The interpretation of these findings must be considered in the context of several methodological limitations.

Selection bias

The utilization of purposive sampling method with a small sample size, increases the risk of selection bias, potentially limiting the generalizability of the results to the broader population of pregnant women.

Limited hematological parameters

The study's assessment of iron status was incomplete, as key indicators such as serum ferritin and transferrin were not measured. Consequently, the intervention's impact on iron stores and the comprehensive iron status of participants could not be determined.

Short Intervention and Follow-up Period

The 30-day duration was sufficient to demonstrate short-term hematological changes but is insufficient to evaluate the intervention's long-term effects on maternal nutritional status or critical pregnancy outcomes, such as birth weight and incidence of prematurity.

Reliance on Self-Reported Data

Dietary intake data were collected via self-reported food recalls, which are susceptible to recall bias and social desirability bias. Respondents may have inaccurately reported their consumption, particularly of specific food groups, potentially confounding the results.

Unmeasured Confounding Variables

Although the study adjusted for several known confounders, including age, occupation parity, and gestational age, residual confounding from unmeasured or unknown factors affecting hemoglobin levels among pregnant women with anemia cannot be ruled out.

Statistical Power

Nevertheless, these limitations, the study possesses notable methodological strengths. The quasi-experimental design, incorporating a control group, enhanced internal validity. Hemoglobin levels were quantified using an accurate and reliable Nihon Kohden hematology analyzer. The statistical analysis, employing paired and independent *t*-tests on normally distributed data, provided robust power, with the intervention effect reaching statistical significance ($p < 0.05$). Finally, the intervention's basis in locally accessible, acceptable, and inexpensive food ingredients enhances its potential for scalability and sustainable implementation within community-based programs.

5 CONCLUSION

This study demonstrates that the co-administration of moringa-soymilk along with iron supplementation significantly increases hemoglobin levels in pregnant women with anemia. The intervention group exhibited a significant mean increase in hemoglobin ranging from 9.69 g/dL to 10.61 g/dL ($p < 0.05$), whereas the change in the control group from 9.70 g/dL to 10.44 g/dL, was not statistically significant. These findings confirm that moringa-soymilk is an effective, safe, nutritious, and organoleptically acceptable food-based intervention with the potential to support efforts to address anemia in pregnant women.

The results hold substantial promise for public health policy, underscoring the potential of sustainable, affordable, and culturally appropriate nutritional interventions to complement national anemia reduction programs.

This research provides evidence that locally sourced, food-based strategies can be effectively integrated into maternal nutrition programs. Policymakers and health practitioners should consider promoting the development and distribution of such innovative, ready-to-use food products to improve the scalability and accessibility of anemia prevention efforts at the community level.

As a direction for future research, larger sample sizes and longer-term, longitudinal designs should be employed to evaluate the sustainability of the hemoglobin response, assess impacts on iron stores (e.g., serum ferritin and transferrin saturation), and determine the intervention's long-term effects on maternal and neonatal outcomes, including birth weight and gestational age. Furthermore, research into the precise physiological and biochemical mechanisms—such as nutrient bioavailability and synergistic effects on erythropoiesis, would elucidate the pathway by which this combination confers its benefit.

Furthermore, it is essential to develop innovative, ready-to-eat local food products based on moringa and soybeans to support national policies aimed at preventing anemia and improving the nutritional status of pregnant women at the community level.

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