

The Effect of Fresh Moringa Leaf Consumption During Pregnancy on Maternal Hemoglobin Level in Southern Ethiopia: Multilevel Analysis of a Comparative Cross-Sectional Study

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Purpose: Anemia, especially iron-deficiency anemia during pregnancy, significantly impacts maternal health, fetal growth, and development. Moringa leaf is an iron-rich food that can overcome anemia, but there is a lack of evidence on the association between fresh moringa leaf consumption and maternal hemoglobin level during pregnancy. The aim of this study is to test the effect of fresh moringa leaf consumption during pregnancy on maternal hemoglobin levels in southern Ethiopia.

Methods: A community-based comparative cross-sectional study was conducted from May to June 2022 among 230 fresh moringa leaf consumers and 230 non-consumers pregnant women. Data were collected using an interviewer-administered structured questionnaire and hemoglobin level was determined by HemoCue Hb 301. Multivariate multilevel linear regression models were fitted using Statistical Software for Data Science (STATA) version 14.

Results: The overall mean hemoglobin level among pregnant women was 11.76 g/dl \pm 1.47 [12.06 g/dl \pm 1.22 among fresh moringa leaf consumers and 11.45 g/dl \pm 1.64 among non-consumers] with a significant coefficient of association (β) of 0.90 g/dl [β = 0.90 g/dl, 95% CI: 0.54, 1.27]. A number of under-five children, bleeding during the current pregnancy, male-headed household, and current antenatal care visit were the individual-level factors. Distance from the nearest health facility and urban dweller was identified as the community-level factor associated with maternal hemoglobin level during pregnancy.

Conclusion: This study showed that the consumption of fresh moringa leaf during pregnancy increases the level of hemoglobin. So policymakers and maternal and child health program managers need to target moringa tree scale-up and encourage fresh moringa leaf consumption during pregnancy, but its use needs additional rigorous clinical trials. In addition to this, mark the above factors in their efforts to increase maternal hemoglobin levels during pregnancy.

Keywords: fresh moringa leaf consumption, hemoglobin level, pregnant women, Southern Ethiopia

Introduction

Anemia, particularly iron-deficiency anemia during pregnancy, significantly affects maternal health, fetal growth, and development.^{1,2} During pregnancy, anemia is diagnosed when the hemoglobin (Hgb) level is below 11g/dl. Low hemoglobin levels result in insufficient oxygen and nutrient delivery to the body, placenta, and fetus. It also serves as a proxy for nutritional and health status and is associated with a higher incidence of maternal and infant morbidity and mortality.^{3–5}

Globally, in 2019, over 500 million (29.9%) reproductive-age women were anemic, of which 36.5% were pregnant women.⁶ Of these pregnant women, 42.7% live in low- and middle-income countries.⁷ In sub-Saharan Africa, the prevalence of anemia during pregnancy was 35.6%,⁸ with a pooled prevalence of 26.4% in Ethiopia.⁹ Between 2011 and 2016, there was a 7% rise in the incidence of anemia among women of reproductive age.¹⁰ The magnitude among pregnant women varies from 25.2% to 56.8%, with more than half of it caused by iron deficiency anemia.^{11–15}

Studies have indicated that anemia during pregnancy increases the risk of maternal death,¹⁶ preterm birth,¹⁷ postpartum complications,¹⁸ perinatal asphyxia,¹⁹ intra uterine growth retardation,¹⁷ small for gestational age,²⁰ childhood under nutrition,²¹ neonatal mortality,²² reduced cognitive and motor development in later life^{19,23} and increased risk of developing chronic non-communicable diseases.²⁴ Due to this, it is crucial to concentrate on maternal nutrition during pregnancy in order to reach the global nutrition target of a 50% reduction of anemia in women of reproductive age by 2025²⁵ and in directly to achieve SDG 2030.²⁶

Despite different interventions to reduce the incidence of anemia like dietary counseling and iron with folic acid supplementation (IFAS) during pregnancy through antenatal care; but adherence to IFAS was below 50%^{27–31} which is insufficient to address the problem as needed. As a result, consumption of culturally accepted iron-rich foods source is essential to prevent the incidence of anemia during pregnancy.³²

Moringa is a culturally accepted food source rich in iron and abundant in southern Ethiopia, where 100g of locally cooked fresh moringa leaf provides 43.5% of the recommended daily iron intake for adults.³³ However, it is underutilized.^{34,35} Previous studies have shown that consuming moringa reduces malnutrition, pregnancy complications, and micronutrient deficiencies.^{33,36–39} In addition, a review of the current evidence shows that consumption of moringa leaf during pregnancy increases iron levels and prevents anemia during pregnancy.⁴⁰ Study conducted in different areas of the world revealed that before and after intervention of moringa capsule or powder among pregnant women, hemoglobin level mean and standard derivation was 11.19 ± 0.8 and 11.93 ± 0.9 in Indonesia,³⁸ 10.17 ± 1.0 and 12.12 ± 1.09 in Kanyakumari District,⁴¹ 10.9 g/dl and >11 g/dl in Waimital Village, Indonesia,⁴² respectively. The average difference in hemoglobin level of pregnant women before and after moringa administration was 1.82 g/dl⁴³ and 0.73 ± 1.29 in Indonesia.³⁸

The majority of moringa research has concentrated on the use of moringa extract (capsules and dry powder). However, our research specifically examines the effect of fresh moringa leaf consumption during pregnancy on hemoglobin level scares in Ethiopia. Hence, this particular study aims to investigate the effects of consuming fresh moringa leaves during pregnancy on hemoglobin level and identify any individual or community-level factors contributing to hemoglobin levels among pregnant women in south Ethiopia.

Materials and Methods

Study Setting, Design and Period

A community-based comparative cross-sectional study was conducted from May to June 2022 in Arba Minch Zuria and Chench district of Gamo zone. The main towns of Arba Minch Zuria and Chench district are located 434 kms and 443 kms far to the south of Addis Ababa, the capital city of Ethiopia, respectively, with a total population 353,019 in the year 2021/22 as projected from the 2007 Ethiopian census with 12,214 expected number of pregnancy. There are two hospitals, nine health centers, sixty-three health posts, and different levels of private health facilities providing curative, preventive, and rehabilitative services for the population.

Population of the Study and Inclusion Criteria

The source populations for this study were all pregnant women living in Arba Minch Zuria and Chench district for at least 6 months. The study population was selected pregnant women with gestational age between 20 and 26 weeks and not unable to communicate at the time of recruitment living in the selected kebeles (the smallest administrative units in Ethiopia) of Arba Minch Zuria and Chench district.

Sample Size Determination and Sampling Method

The sample size was calculated by comparing two-population means of equal sample size for the two groups using G*Power⁴⁴ version 3.1.9. Assuming 95% CI, 80% power, 11.494 ± 1.24 expected mean and SD of hemoglobin level among fresh moringa leaf consumers and 9.675 ± 1.28 expected mean and SD of hemoglobin level among non-consumers,⁴³ consumer to non-consumer ratio of 1:1, 10% possible non response, using effect size of 0.3^{45,46} and design effect of 1.5. Based on the above assumptions, the calculated sample size was 460 (230 consumers and 230 non-consumers). The sample was obtained using a multistage sampling method. Initially, 20 kebeles, 10 from Arba Minch Zuria and 10 from Chench district were selected using

lottery methods. Eligible pregnant women were identified and the sample was allocated proportionally based on the number of eligible pregnant women in each kebele. Then, the required sample was designated using computer-generated simple random sampling techniques.

Study Variable

Pregnant woman hemoglobin level was the outcome variable and community-level explanatory variables were consumption of fresh moringa leaf, community wealth status, community source of drinking water, community media exposure, place of residence and distance from the nearest health center; whereas, individual-level variables were socio-demographic, obstetric, health and dietary related factors.

Data Collection Instrument and Techniques

Ten nurses and two public health professionals were used to collect and supervise the data collection, respectively. Two days of training were conducted for data collectors and supervisors. Three laboratory technicians measured the hemoglobin level. Data were collected using a pre-tested, face-to-face interviewer-administered structured questionnaire that address socio-demographic, obstetric, health and dietary related factors.

Data were collected digitally using an open-source toolkit (kobo Collect). A template of questions was prepared in a computer database and deployed to the server then downloaded to the cell phones of data collectors. Training was provided on how to download the template and upload the data. HemoCue Hb 301 machine was used to measure hemoglobin level.

Operational Definition

Moringa Consumption

Women, who consumed fresh moringa leaf in the last one month for at least four days per week, regardless of amount or frequency, we classified as consumer and not consumed ever as non-consumer.

Measurement

Hemoglobin Level

Hemoglobin level of pregnant women was measured using HemoCue Hb 301 machine, safety lancet and microcuvette. The machine was a pre calibrated instrument designed for the measurement of hemoglobin concentration. A blood sample is collected from each participant using a figure-pricking method to collect drops of blood from the left ring finger. The first and second drops of blood were wiped away. A third drop was then used to measure hemoglobin levels. Blood was drawn through microcuvettes and inserted into the HemoCue machine and the results were recorded.⁴⁷ We used the adjustment factor for altitude correction in order to obtain the comparison of both groups.⁴⁸

Women nutritional status was assessed using mid upper arm circumference (MUAC) and measured using a flexible non stretchable standard tape measured at the mid-point between the tips of the ulna. Measurements were taken on the right arm with an accuracy of 0.1 cm. Women with MUAC greater than or equal to 23cm are considered well-nourished and less than 23 cm as under nourished.⁴⁹

Minimum Dietary Diversity- Women (MDD-W)

The data of minimum dietary diversity score was collected by using a 24 hour dietary recall method according to FAO's 2016 guideline. To each food group that a woman ate in 24 hours of the day before the data collection score of 1 for yes was given otherwise 0 for no. The score was made by counting the number of food groups. Finally, a woman who had got 5 scores or more out of 10 was categorized as adequate otherwise inadequate dietary diversity.⁵⁰

Data Processing and Analysis

Data were checked online, approved for its completeness and consistency daily and downloaded after completion of data collection, then exported to STATA version 14 for analysis. Descriptive statistics such as frequency, percentages, mean and standard deviations were used to describe the characteristics of the study participants. Exploratory factor analysis

using the principal components analysis (PCA) method was employed to determine household wealth status. An Independent *t*-test was employed to compare the mean hemoglobin level among fresh moringa leaf consumer and non-consumer.

Bivariate analysis was employed on all individual and community level explanatory variables to assess their association with the outcome variable. Variables with a p-value of less than 0.25 in bivariate analyses and plausible variables were included in multivariable multilevel linear regression analysis. First, we estimated an intercept-only model (with only the outcome variable). Intra-class correlation coefficient (Icc) was checked to examine clustering and the extent to which community-level factors explained the unexplained variance of the null model (Icc=0.1212, indicating the preference of multilevel model). Secondly, we included all individual-level variables in the model (model I). In the third stage, we fitted community-level variables only (model II) and the final model was fitted with both individual and community-level variables (model III). Model III, the model with the lowest Akaike's information criteria (AIC) and Bayesian information criterion (BIC), was selected as the best model for an analysis. β coefficients with 95% CI in the multivariable multilevel mixed effect linear regression analysis were used to decide whether those individual and community-level variables were statistically significant ($p < 0.05$) or not. The Breusch-Pagan/Cook-Weisberg and skewness/kurtosis tests were used to check the assumptions of equal variance and normality.

Results

Socio Demographic and Health Related Characteristics of Fresh Moringa Leaf Consumer and Non-Consumer

A total of 460 (230 fresh moringa leaf consumer and 230 non-consumer) participated in the study. There is no significant difference between the two groups (Table 1) in marital status, household head, number of family member ("Supplementary Table 1"), number of pregnancy, history of abortion prior to this pregnancy, pregnancy status, had

Table 1 Socio-Demographic, Health, and Dietary-Related Characteristics of Fresh Moringa Leaf Consumers and Non-Consumers Pregnant Women in Southern Ethiopia

Variable	Total No (%) (n=460)	Consumer No (%) (n=230)	Non-Consumer No (%) (n=230)	p-value
Marital status				0.37
Married	458 (99.57)	229 (99.57)	229 (99.57)	
Other	2 (0.43)	1 (0.38)	1 (0.38)	
Household head				0.38
Male	438 (95.22)	217 (94.35)	221 (96.09)	
Female	22 (4.78)	13 (5.65)	9 (3.91)	
Number of Family members				0.26
Less than or equal to five	402 (87.39)	205 (89.13)	197 (85.65)	
Greater than five	58 (12.61)	25 (10.87)	33 (14.35)	
Number of gravida				0.19
Primigravida	113 (24.57)	58 (25.22)	55 (23.91)	
Multigravida	306 (66.52)	157 (68.26)	149 (64.78)	
Grand multigravida	41 (8.91)	15 (6.52)	26 (11.30)	

(Continued)

Table 1 (Continued).

Variable	Total No (%) (n=460)	Consumer No (%) (n=230)	Non-Consumer No (%) (n=230)	p-value
Abortion before this pregnancy				0.30
No	407 (88.48)	200 (86.96)	207 (90.00)	
Yes	53 (11.52)	30 (13.04)	23 (10.00)	
Pregnancy status				0.23
Unplanned	154 (33.48)	83 (36.09)	71 (30.87)	
Planned	306 (66.52)	147 (63.91)	159 (69.13)	
Gestational age				0.29
20 to 23wks	92 (40.00)	81 (35.22)	173 (37.61)	
24 to 26	138 (60.00)	149 (64.78)	287 (62.39)	
Had Nausea/ vomiting				0.70
No	218 (47.39)	107 (46.52)	111 (48.26)	
Yes	242 (52.61)	123 (53.48)	119 (51.74)	
Anemia during the current pregnancy				0.79
No	445 (96.74)	223 (96.96)	222 (96.52)	
Yes	15 (3.26)	7 (3.04)	8 (3.48)	
Bleeding during the current pregnancy				0.31
No	451 (98.04)	224 (97.39)	227 (98.70)	
Yes	9 (1.96)	6 (2.61)	3 (1.30)	
Animal source food (ASF)				0.06
Not consume ASF	113 (49.13)	133 (57.83)	246 (53.48)	
Consume ASF	117 (50.87)	97 (42.17)	214 (46.52)	
Meal frequency per day				0.85
Three times and less	106 (46.09)	108 (46.96)	214 (46.52)	
Four and more times	124 (53.91)	122 (53.04)	246 (53.48)	

nausea/vomiting, history of anemia during current pregnancy, history of bleeding during current pregnancy, meal frequency per day and consumption animal source food (ASF) (“[Supplementary Table 2](#)”).

Dietary Related Characteristics of Fresh Moringa Leaf Consumer and Non-Consumer

More than three-fourth of the participants, 72.17% of fresh moringa leaf consumers and 81.83% of non-consumers, were well nourished and more than half of the participants consumed at least one additional meal. One hundred and thirty six (59.13%) of fresh moringa leaf consumers and 61 (29.13%) non-consumers received dietary counseling during pregnancy. One hundred and sixteen (50.43%) fresh moringa leaf consumers and 58 (25.22%) non-consumers consumed adequate dietary diversity. One hundred and seventeen (50.87%) fresh moringa leaf consumers and 97 (42.17%) non-

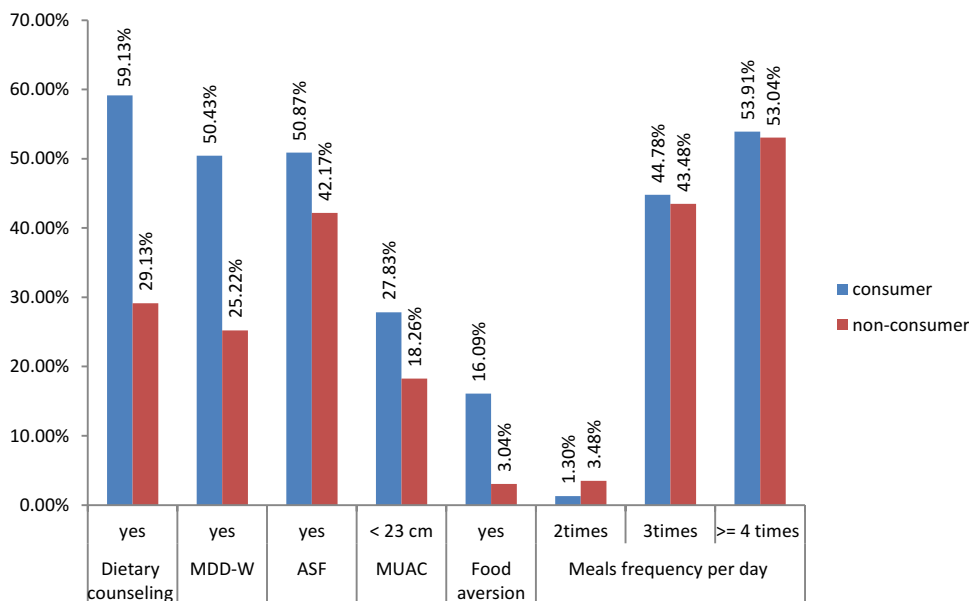


Figure 1 Dietary-related characteristics of fresh moringa leaf consumer and non-consumer pregnant women in Southern Ethiopia.

consumers consumed animal source food (Figure 1). Our study showed that no significant association between hemoglobin level and animal-based food consumption, intake of 5 or more food groups, and receiving dietary counseling.

The Association Between Moringa Leaf Consumption and Maternal Hemoglobin Level

The mean hemoglobin level of the study participants was 11.76 g/dl ± 1.47 (11.45 g/dl ± 1.64 among consumers and 12.06 g/dl ± 1.22 among non-consumers). The mean hemoglobin level was 0.61 g/dl [95% CI 0.34, 0.87] higher among fresh moringa leaf consumer than non-consumer (Table 2).

Factors Associated with Hemoglobin Level Among Pregnant Women

An intra-cluster correlation coefficient (Icc) of 0.1212 for the null model indicated that 12.12% of the variability in hemoglobin levels among pregnant women was due to intra-cluster variability, also confirming the use of multilevel models for analysis. The between cluster difference decreased from 12.12% in null model to 11.75% in the Model I that had only the individual-level variables. Again, the between cluster differences were slightly decreased from 11.75% in model I to 10.88% in the community level only model (Model II). Finally, Icc decreased to 11.72% in the complete model (Model III) that encompassed both individual and community-level factors. Log likelihood ratio test was established -813.25733, 1 in the null model and -773.98152, 78.55 in the final model (Model III), this shows that increment and confirms model adequacy. The values of AIC were confirmed as 1632.515 in the null model and 1569.963 in the final model (Model III) this expresses a succeeding decrease, which shows that there is a considerable

Table 2 The Effect of Fresh Moringa Leaf Consumption During Pregnancy on Maternal Hemoglobin Level Among Pregnant Women in Southern Ethiopia

Fresh Moringa Leaf	Observation	Mean ± SD	[95% C I]	t- test	p-value
All participant	460	11.76 ± 1.47	11.62, 11.89		
Consumers	230	12.06 ± 1.22	11.90, 12.22	4.50	0.001
Non-consumers	230	11.45 ± 1.64	11.24, 11.67		
Mean difference, 95% CI		0.61g/dl	0.34, 0.87		

improvement from the empty model to individual and community level-only models and again to the complete model. This confirms the goodness-of-fit of the final model established in the analysis. Hence, model III was chosen for forecasting the change of hemoglobin among pregnant women.

The final model (Model III) shows that hemoglobin levels among pregnant women who consumed fresh moringa leaf were 0.90 g/dl ($\beta = 0.90$, 95% CI: 0.54, 1.27) higher than those who did not. The level of hemoglobin was 0.57 g/dl higher among women who lived in urban as compared to those who lived in rural ($\beta = 0.57$, 95% CI: 0.22, 0.92). Pregnant women from male-headed households had hemoglobin levels 0.87 g/dl ($\beta = 0.87$, 95% CI: 0.40, 1.33) higher than those from female-headed households. Hemoglobin levels were 0.49 g/dl higher among pregnant women with one child than those with two children under 5 years of age ($\beta = 0.49$, 95% CI: 0.17, 0.82). The hemoglobin level of women who attend antenatal care in the current pregnancy was 0.45g/dl ($\beta = 0.45$, 95% CI: 0.17, 0.74) higher than their counterpart. Hemoglobin level was 1.07 g/dl decreased among women who faced bleeding in the current pregnancy as compared to their counterpart ($\beta = -1.07$, 95% CI: -1.91, -0.22). As distance to the nearest health center increased by 1km, the women's hemoglobin level decreased by 0.10g/dl ($\beta = -0.10$, 95% CI: -0.15, -0.06) (Table 3).

Table 3 Multilevel Mixed Effect Linear Regression Analysis of Individual and Community-Level Factors Associated with Hemoglobin Level Among Pregnant Women in Southern Ethiopia

Variable	Null Model	Model I	Model II	Model III
Hemoglobin level	11.74 (11.45, 12.02)**			
Health facility distance			-0.08 (-0.12, -0.029)**	-0.10 (-0.15, -0.06)**
Moringa Consumption				
No			I	I
Yes			0.99 (0.61, 1.36)**	0.90 (0.54, 1.27)**
Place of residence				
Rural			I	I
Urban			0.63 (0.27, 0.98)*	0.57 (0.22, 0.92)*
House hold head				
Husband		0.75 (0.26, 1.23)*		0.87 (0.40, 1.33)**
Wife		I		I
Number of under 5 children				
No		0.27 (-0.06, 0.61)		0.32 (-0.01, 0.64)
One		0.47 (0.13, 0.81)*		0.49 (0.17, 0.82)*
Two		I		I
Bleeding faced in this pregnancy				
No		I		I
Yes		-1.06 (-1.95, 0.17)*		-1.07 (-1.91, -0.22)*
ANC visit				
No		I		I
Yes		0.45 (0.16, 0.75)*		0.45 (0.17, 0.74)*

(Continued)

Table 3 (Continued).

Variable	Null Model	Model I	Model II	Model III
Variance				
Between district	0.26 (0.11, 0.64)	0.24, (0.09, 0.58)	0.21(0.09, 0.53)	0.21 (0.08, 0.52)
Between individual	1.90 (1.67, 2.17)	1.78 (1.56, 2.03)	1.74 (1.53, 1.99)	1.61 (1.41, 1.83)
ICC%	12.12%	11.75%	10.88%	11.72%
Model comparison				
Log likelihood	-813.25733, 1	-798.01195, 30.49	-792.06777, 42.38	-773.98152, 78.55
AIC	1632.515	1612.024	1596.136	1569.963
BIC	1644.908	1645.074	1620.923	1615.407

Notes: I: Reference group, *p-value 0.05–0.01, **p-value <0.01.

Discussion

In this study, consumption of fresh moringa leaf had a significant association with the hemoglobin level of pregnant women in the study area. The hemoglobin level was 0.90g/dl higher among fresh moringa leaf consumers than non-consumers. This is in line with previous studies conducted in Indonesia, India, Senegal, Bangladesh and recent reviews^{37,38,42,51–56} where the intake of moringa in different forms treats anemia. This may be due to the nutrient content of moringa. Moringa is an iron-rich food source with easily digestible proteins, vitamins and minerals.^{33,57} Also, consumption of fresh moringa leaf increases the level of serum protein, vitamins A and C.^{36,42} Studies indicated that vitamin C enhances the bioavailability and absorption of iron also serum retinol maintains normal hemoglobin levels and serum protein facilitate iron absorption and transportation.^{43,58–61} These imply that the consumption of fresh moringa leaf had an effect on hemoglobin level.

In this study, the mean hemoglobin level was decreased by 0.10 g/dl [95% CI: -0.15, -0.06] for each km increase in distance to the nearest health center. This finding is supported by studies conducted in eastern Africa and sub-Saharan Africa.^{62,63} This may be due to being near to health facilities may easily access health facilities for different services and may increase the chance of dietary counseling and the likelihood of timely diagnosis for infectious disease and contribute to preventing anemia.^{64–68}

Our study shows that the level of hemoglobin in pregnant women was 0.57 g/dl higher among urban dwellers as compared to rural dwellers, which is in line with studies conducted in different parts of Ethiopia and sub-Saharan Africa.^{9,65,69–71} This might be due to the fact that women living in urban setting had increased intake of iron-rich food, diversified food, adherence to IFAS, accessible for health service, health information and media; this might enhance knowledge and practices that reduce the incidence of anemia during pregnancy. Also, urban pregnant women had higher decision-making power, employment status, and health seeking behaviors, which may reduce the incidence of anemia during pregnancy. Moreover, being a rural dweller increases the likelihood of infection, which might lower the level of hemoglobin.

The hemoglobin level of pregnant women from male-headed households was 0.87 g/dl higher than those from female-headed household. This finding was supported by studies conducted in sub-Saharan Africa and Ethiopia.^{71,72} This may be due to female household head was relation between low level of education and employment, this makes their livelihood insecure and leads to food insecurity; finally end up with different health problems including iron deficiency. In addition, the low awareness and treatment-seeking behavior of female household heads contribute to anemia.^{73–75}

The level of hemoglobin was 0.49 g/dl higher among pregnant women who had one child as compared to those who had two children below the age of 5 years. This is supported by studies conducted in various regions of Ethiopia.^{65,72,76} One possible explanation for this is that women experience a depletion of iron due to the frequent pregnancies and resulting loss of blood during delivery and postnatal period. If a woman becomes pregnant too soon after giving birth, she

may not have had enough time to replenish the lost blood, which increases her susceptibility to anemia.^{77,78} Additionally, stress and birth-fear can lead to inadequate food intake in women who give birth more frequently, contributing further to the development of anemia⁷⁹ and also to this one possible reason for this could be that having more young children under the age of five could result in a greater workload and less time for a woman to take care of herself and provide food for her family.⁸⁰

Hemoglobin level was 1.07 g/dl decreased among mothers who faced bleeding in the current pregnancy as compared to their counterpart. This finding is comparable with study conducted in north-west and central Ethiopia.^{76,81} This may be due to the fact that bleeding during the current pregnancy causes depletion of iron which in turn causes anemia.

The hemoglobin level of mothers who attend antenatal care in the current pregnancy was 0.45 g/dl higher than their counterparts. This is supported by recent systematic review and meta-analysis in Ethiopia.⁹ This possible reason might be that when ANC visits increases the opportunity for getting a sufficient number of iron folate tablets and increases adherence to iron with folic acid.⁸²

It is the fact that consumption of diversified⁸³ and animal source food raises the likelihood of dietary iron intake⁸⁴ consequently increases the hemoglobin level. Contrary to this fact, in our study and other studies conducted in different parts of the world, we lack significant association between hemoglobin level and consumption of animal-based food studies carried out in Ghana⁸⁵ and rural Bangladesh.⁸⁶

Similarly, we found no significant connection between dietary diversity and maternal hemoglobin levels, which agrees with the rural Bangladesh study.⁸⁶ It may be due to the use of 24 hour recall method to identify consumption of diversified and animal-based food that under estimate the intake because the method does not identify the usual dietary intake.

Regarding counseling, our study found that women who did not receive dietary counseling during ANC visit had no statistically significant association with hemoglobin levels, which is consistent with a study done in Indonesia⁸⁷ but inconsistent with a study conducted in Ethiopia.⁸⁸ A plausible explain this discrepancy, it is possible that the quality and content of dietary counseling received may vary. Therefore, further research needs to investigate the type of information provided during ANC encounters and how it is imparted.

Strength and Limitation

The study relied on the participant's oral responses regarding their history of fresh moringa leaf consumption during the present pregnancy and does not inquire as to how much was consumed daily; therefore, this could have some impact on the results. To minimize recall bias we used consumption history before one month of the study period. Moreover, information on some important confounding variables such as malaria and intestinal parasitic infection were not investigated but to reduce this we used current pregnancy history of malaria and intestinal parasitic infection attack including frequency, bed net use, and intestinal parasitic infection drug use as treatment. In addition to this, we included the key potential confounders in the multivariable regression model. Another limitation is the shortage of similar studies limited us from making further comparative discussions.

Conclusion

Our findings reveal that consumption of fresh moringa leaf during pregnancy can increase hemoglobin level. Hemoglobin level was also found to be affected by place of residence, number of under-five children, bleeding during the current pregnancy, current antenatal care visit, headed of the households, and distance to the nearest health facilities. Thus, policy maker's program planners, clinical and public health interventions should enhance moringa leaf consumption, birth spacing, maternal health service utilization and accessibility of health facilities.

Abbreviations

ANC, antenatal care; CI, Confidence interval; CSA, Central statistics agency; FAO, Agriculture Organization of the United Nation; GA, gestational age; IRB, Institutional Review Board; MUAC, Mid Upper Arm Circumference; PCA, principal components analysis.

Data Sharing Statement

All related data and its supporting information are within the paper.

Ethics Approval and Informed Consent

All methods of this study were carried out in accordance with the declaration of Helsinki-ethical principle for medical research involving human subjects. An ethical approval and clearance was obtained from the institutional review board (IRB) institute of health, Jimma University with a reference number of (THRPG1/469/2022) before the commencement of data collection. A letter of cooperation was obtained from the Gamo zone health office. Informed consent was obtained from the study participants after informing the purpose of the study.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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