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Consumption of Mixed Indigenous Vegetables: A Solution to Low Hemoglobin Levels among Pregnant Women in Babati, Tanzania

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Abstract

Pregnancy-related anemia is a critical health issue affecting a larger number of pregnant women in Tanzania affected. The study examined the impact of consuming locally grown indigeneous vegetables on iron intake and anemia prevention. The study utilized a cross-sectional design to investigate the impact of consuming locally grown indigenous vegetables on iron intake and anemia prevention among 340 pregnant women in Babati District, Tanzania. Participants were recruited from antenatal care services at four health facilities within the district. Dietary assessments were conducted to evaluate food consumption patterns and Dietary Diversity Scores (DDS). were calculated to determine the variety of food groups consumed. Indigenous vegetables were analyzed for the iron, vitamin C, and phytate content to assess their nutritional composition. Statistical analyses conducted included Chi_2 ($\chi 2$) tests and Spearman rank correlations to evaluate the relationships between socio-demographic factors, dietary practices, and anemia prevalence. The prevalence of anemia was 45%, with a significant association between anemia and maternal age ($P < 0.04$, $\chi 2 = 6.43$), as older women (36–49 years) were less likely to be anemic compared to younger women (≤35 years). Marital status also correlated with anemia ($P < 0.04$, $\chi 2 = 4.1$), with married women showing a lower prevalence.

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Dietary diversity was limited, with only 55.6% of participants consuming five or more food groups (DDS ≥ 5). Indigenous vegetables, such as sweet potato leaves and amaranth combined with lemon juice, showed high vitamin C content (43.2 ± 0.26 mg/g), enhancing iron absorption. Hygiene practices like hand washing after toilet use were associated with reduced anemia risk ($P < 0.0022$, $\chi 2 = 9.352$). This study highlights the importance of indigenous vegetables, dietary diversity, and good hygiene in reducing anemia among pregnant women in rural Tanzania, emphasizing the need for nutrition education and improved access to iron-rich foods.

Introduction

Maternal health is a public health concern in the global agenda for sustainable development. Among the challenges related to human maternal health, pregnancy-related anemia is of public health importance. This condition poses significant risks to both mothers and unborn children making it crucial to prioritize effective interventions.[1,2] Anemia occurs when blood has a lower-than-normal amount of red blood cells or hemoglobin. The World Health Organization (WHO) defines anemia in pregnancy as a condition in which hemoglobin levels drop below 11.0 g/dl. Moreover, WHO further categorizes the prevalence of anemia as a public health concern into three levels; mild (Hb levels 9- 10.9g/dL), moderate anemia (Hb levels 7-8.9g/dL), and severe anemia (Hb levels less than 7g/dL). Globally, about 1.62 billion people accounting for 25% of the entire population are anemic with 56 million of them being pregnant women.[3] Studies have shown that, about 90% of women have iron stores of < 500 mg (serum ferritin <70 mg/l) worldwide, which is insufficient to meet the increased iron needs during pregnancy and postpartum.[4]

In Tanzania, iron deficiency anemia among pregnant women remains a significant public health issue with a prevalence rate of 57% of all pregnant women. Factors contributing to this high prevalence include lack of formal education, food insecurity, irregular and infrequent antenatal clinic visits, absence of health insurances and reliance on home deliveries.[5] Some interventions have been done in Tanzania, such as nutrition education and supplementation with iron and folic acid among pregnant women. However, the prevalence of anemia is still a severe public health problem.[6] While interventions such as nutrition education and iron and folic acid supplementation have been implemented, anemia continues to be a severe problem. Challenges to effective implementation include delayed initiation, poor ANC attendance, accessibility such as geographic barriers, financial constraints, inadequate healthcare infrastructure and insufficient distribution of supplements particularly in rural areas. Misconception about pregnancy and iron supplements further exacerbate these challenges alongside reported side effects such as nausea, vomiting, and dizziness.[6]

Given these challenges, there is a pressing need for an innovative approach to reduce anemia risk among pregnant women.[7] Possible strategies could include enhancing nutritional education, improving supplementation adherence, and ensuring access to healthcare services.[8] However, it is important to consider locally viable solutions that align with the community sources and cultural practices to effectively address the issue. These resources include local food practices, agricultural preferences, and cultural preferences that involve dietary habits. By leveraging these factors, interventions can be more sustainable and culturally appropriate. Therefore, this study aimed to investigate indigenous vegetables locally consumed by women in Babati in order to harness their potential in optimizing iron intake as an innovative way to alleviate anemia symptoms and boost hemoglobin levels among pregnant women in Babati. This is an empowering strategy for the prevention and management of pregnancy-related anemia. The choice of indigenous vegetables reflects their inherent accessibility, affordability, and simplicity of cultivation, aligning with the local context of Babati District in Tanzania.

Material and Methods

Study Design and Settings

This study was a cross-sectional, hospital-based survey conducted in Babati district, Tanzania at four health facilities: Mrara district hospital, Galapo

health center, Bonga health center, and Magugu health center. The study sites were selected for their central role in providing antenatal care (ANC) services. To ensure a representative sample, participants were selected using a stratified random sampling method based on facility size and patient load. Pregnant women in their second and third trimesters were randomly approached while those of the first trimesters or with pre-existing conditions affecting haemoglobin levels were excluded. Quality control measures included pre-testing of tools, minimizing missing data and employing imputation methods when necessary. Ethical approval was obtained from the National Institute for Medical Research (NIMR) and informed consent was collected from all participants. The study design and sampling strategy were aimed at ensuring a diverse representative sample while maintaining data validity and minimizing bias.

Sample Size Calculation

Determining the appropriate sample size is crucial for ensuring validity and correct representation of the population of the study results. For this study, anemia prevalence of 32.7% in Babati with the significance level of 95% with a sampling error of 5% were used. The significance level (1.96) corresponds to a 95% confidence level, ensuring that the true population parameter would fall within the calculated range 95 times out of 100. The formula used to calculate the sample size is shown in Equation (1)

$$\text{Sample size } (n) = (z^2\, pq) / e^2 \quad \ldots(1)$$

where, n Denotes sample size, z is the Z table value at a 95% confidence interval level of 1.96, P denotes the largest population variability at 32.7%, e denotes sampling error at 5% and q denotes a value equivalent to 1-p = 0.673. Based on these values, the calculated sample size was 338, rounded up to 340 participants

Data Collection

A structured questionnaire was used to collect information from study participants. Socio-demographic and socio-economic factors influencing anemia during pregnancy were collected from all study participants. To capture a comprehensive understanding of dietary practices and the context around anemia management, focus group discussions (FGDs) and key informant interviews (KIIs) were conducted with local health workers, community elders, and pregnant women. These discussions focused on cultural food preferences, traditional meal patterns, taboos, and hygiene practices. This ensured that the proposed dietary interventions were not only scientifically sound but also aligned with locally available foods and cultural practices. A randomly selected group of ten women from each health facility were followed up at their homes to observe how they prepared vegetable decoctions for prevention and management of anemia during pregnancy.

Collection and Preparation of Vegetable Samples for Micronutrient Analysis

The selection of vegetables for the study was guided by a purposive sampling procedure which focused on indigenous vegetables commonly found in the local markets of Babati district as shown in Table 1. These vegetables were chosen based on their traditional use in the community, their availability, and their known nutritional benefits, particularly in relation to iron content and their potential role in preventing anemia. The goal was to identify vegetables that are easily accessible to the target population and are frequently incorporated into their diet. A variety of vegetables were collected from the local market for the study. The collected vegetable samples were transported to Sokoine University of Agriculture in closed polythene bags which were stored in a cool box maintained at 4 ^{o}C. Selected micronutrient contents were then analyzed in the collected samples in triplicate.

Table 1: Types of Indigeneous vegetable collected for nutritional analysis in Babati District

Vegetable Name	Category
Amaranth[26]	Leafy greens
Sweet potato leaves[27, 28]	Leafy greens
Taro leaf[29]	Leafy greens
Blackjack[30]	Leafy greens
Baobab[31, 32]	Fruit powder
Roselle[33]	Flower

Laboratory Analysis

Iron Analysis

The samples were digested using the dry ashing method. A 1.0 g homogenized sample was incinerated into a muffle furnace at 450 °C for 4 hours. The resulting ashes were then dissolved in 10 mL of 10% hydrochloric acid solution and filtered using No 1 Whatman filter paper and diluted to 25 mL with double distilled water. The filtrates were then analyzed for iron content (mg/100 g dry weight) using an Atomic Absorption spectrophotometer (UNICAM 919 AAS, England) for iron at 248.3 nm following AOAC 999.10.9 A calibration curve was prepared using standard $FeSO_4$ solutions, and reagent blanks were included for accuracy.

Vitamin C (Ascorbic Acid) Analysis

Vitamin C was analyzed using the spectrophotometric method described by Binesh *et al*.,.[10] This analysis was conducted to determine its role in iron absorption by preventing the formation of insoluble iron compounds and facilitating Fe^{3+} reduction to Fe^{2+}. Samples were extracted using 3% metaphosphoric acid and analyzed with a Double Beam UV-3000 model X-ma 3000 Spectrophotometer (Human Co-operation, England). The absorbance was measured at 520 nm, and vitamin C content was calculated using a standard calibration curve generated from ascorbic acid solutions. The results were reported as mg/100 g fresh weight. The ascorbic acid content in the vegetable samples was determined using a spectrophotometric method which is recognized for its simplicity, safety, and reliability. This method allows for rapid and precise measurements of ascorbic acid in a wide variety of sample types. Similar techniques have been effectively employed in other studies, such as by Khan *et al*.[11] to measure the vitamin C content in vegetables and fruits. The spectrophotometric method was validated by using known ascorbic acid standards to ensure accuracy and precision in vegetable samples with varying levels of vitamin C. The method's reliability was further confirmed through internal cross-checking with other established methods.

Phytate Analysis

Analysis of phytate content was conducted due to the presence of phosphate groups makes the phytate a highly charged molecule and therefore an excellent chelator, thus can form insoluble complexes with mineral cations such as iron and further decreases its bioavailability when consumed as food. One gram of sample was added to 10 mL 3% TAC (Total Absorbance Chromatograms). Phytates were precipitated as ferric phytate with 0.1% ammonium ferric sulfate. The ferric phytate was converted to ferric hydroxide and sodium phytate by adding 10 mL of 0.5 M sodium hydroxide. The precipitate was boiled and dissolved with the addition of dilute nitric acid, and absorbance of the solution was taken at 519 nm phytic acid content of the samples was calculated using a standard calibration curve and results were expressed as mg/100 g dry weight.

Dietary Diversity Assessment

To evaluate the dietary diversity of participants, the Dietary Diversity Score (DDS) was calculated based on the consumption of various food groups over a 24 hour recall period. Participant reported all foods and beverages consumed, which were categorized into specific groups. The dietary diversity score is a measure of the variety of food groups consumed by an individual within a specific time frame. The DDS was calculated by assigning one point for each food group consumed with the total score reflecting the overall dietary diversity. A higher DDS indicated better dietary diversity, which is usually associated with improved micronutrient intake. The food groups were categorized into nine groups, as per the Food and Agriculture Organization (FAO) guidelines. The groups include starch staples, dark green leafy vegetables, vitamin A rich fruits and vegetables, other fruits and vegetables, organ meat, meat and fish, eggs, legumes, nuts and seeds, milk and milk products. Each unique food group consumed contributed one point to the DDS, with a possible score ranging from 0 to 9. A higher DDS indicates a more diverse diet, which is associated with better micronutrient intake. For the purposes of this study, a DDS of five or more was considered as meeting the minimum dietary diversity requirement for adequate micronutrient intake. The dietary recall data were validated through several methods to ensure accuracy and consistency. First, a subset of 10% of participants was asked to repeat the 24-hour recall after 48 hours. The two sets of data were compared to assess consistency and reduce recall bias. Additionally, the reported anemia status of participants was cross-referenced with their clinical records to verify the consistency of the data. To further enhance accuracy, household observations were conducted for a randomly selected subset

of participants to verify reported food items and preparation practices. All interviews were conducted by trained research assistants to maintain uniformity in data collection and minimize interviewer bias. The 24-hour recall method was standardized with clear, structured questions to ensure reliable reporting. Participants were encouraged to provide detailed and accurate information, with prompts used to clarify any ambiguities.

Statistical Analysis

Data analysis was done using R software version 4.2.2, and commander plug-in for the university level applied statistics (Rcmdr.Plugin.NMBU). version 1.814. Descriptive analysis was applied to continuous variables and presented as mean and standard deviation, while categorical data were presented as frequency and percentage. A chi-square statistical test was used to check whether categorical variables had a relationship with anemia. However, we acknowledge that maternal age is a continuous variable requiring a different approach. To address this, maternal age was categorized into discrete age groups (19-35 and 36-49) to facilitate analysis. This approach commonly used in public health studies allowing for easier interpretation of risk factors.

Results

Demographic and Socioeconomic characteristics of the Study Population

Table 2 presents the demographic characteristics of the interviewed pregnant women population. The data reveals that a majority (91%) of the participants fell within the age range of 15 to 35 years. Notably, the 36-49 age group constituted a smaller proportion compared to other age groups. A significant portion of the participants were married (74.4%), and most households (81%) consisted of 3 to 5 members. A considerable number of pregnant women had completed primary education (57%), while 29% had attained secondary education. Occupationally, a substantial percentage identified as farmers (42%), followed by housewives (33%), with a majority of their husbands also being farmers (51%). Regarding monthly household earnings, 49.41% of respondents reported an income ranging between TZS 101, 000 and 400,000, while 34.11% earned above TZS 400,000 and only 16.47% earned between TZS 20,000-100,000.

Table 2: Demographic characteristics of the study population

Characteristics	N	%
Health facility Location	Number of participants	
Bonga	68	20
Galapo	60	18
Magugu	67	19
Mrara	145	43
Marital Status		
Married	253	74.41
Cohabitating	87	25.58
Household members		
1-2	65	19.11
3-5	165	46.76
Above 5	116	34.11
Mother's education level		
Higher education	29	8.52
Secondary education	97	28.52
Primary education	195	57.35
Illiterate	19	5.58
Mother's occupation		
Employed	27	7.94
Housewife	113	33.23
Business	58	17.05
Farmer	142	41.76
Father's occupation		
Employed	76	22.35
business	92	27.05
Farmer	172	50.58
Household income/month [30]		
20,000-100,000	50	16.47
101,000-400,000	168	49.41
Above 400,000	116	34.11

Good Hygiene Practices, Adequate Nutrition, and Supplement Use in Pregnancy

A comprehensive understanding of hygiene practices, nutritional awareness, and supplement use is crucial for improving maternal health, particularly in the context of pregnancy-related anemia.[12] This section presents the knowledge, attitudes, and behaviors of pregnant women in Babati District, shedding light on how these factors contribute to anemia prevention and overall pregnancy outcomes. The results, as shown in

Table 3 provide insight into the participants health practices, including their use of toilets, hand washing habits, mosquito net usage, and adherence to iron and folic acid supplementation. All participants were reported to have toilets in their households. However, 31% of respondents admitted to not washing their hands after using toilets, while the remaining 69% reported consistent hand washing. Subsequently, our investigation revealed a correlation between hand washing after toilet use and reduced risk for anemia ($\chi 2 = 9.352$, df = 1, $p = 0.0022$), highlighting the importance of this practice in preventing anemia. Conversely, a lack of handwashing after using the toilet was associated with an elevated risk for anemia. In terms of mosquito net ownership, 86% of pregnant women have mosquito nets, and impressively 84% actively used them. Malaria is a known contributor to anemia during pregnancy, therefore proper use of mosquito nets is likely to mitigate the risk for anemia in this population.

In terms of awareness of iron and folic acid supplementation, 63.2% (N=215) of the respondents had knowledge of their importance during pregnancy, while 36.8% (N=125) lacked awareness. This suggests a considerable portion of the population may be uninformed about the role of these supplements in preventing anemia. Despite awareness of iron and folic acid (FeFo) supplements, only 24.7% (N=72) of the respondents showed a proper understanding of the use of FeFo supplements where they said for anemia prevention and fetal development. Adherence to iron and folic acid supplementation was relatively high, with 75.3% (N=256) of the pregnant women reporting consistent usage. However, 24.7% (N=84) did not adhere to the supplementation regimen, potentially leaving themselves at risk of anemia and related complications. Interestingly, despite the relatively high adherence rate, only a quarter of women fully understood the reasons of using iron and folic acid supplements. This knowledge gap highlights the need for targeted educational interventions, as improving understanding could further enhance adherence and reduce health risks. Despite this knowledge gap, adherence to iron and folic acid supplementation was relatively high at 75.3%. This suggests that even when knowledge is limited, other factors such as healthcare provider recommendations or social influences may play a key role in encouraging adherence.

Table 3: Knowledge, Attitudes and Practices of Pregnant Women in Babati District regarding Hygiene, Nutrition, and Supplement Use

Variable	N= 340			
	YES(%)		NO(%)	
Toilet usage	340 (100)		0	(0)
Hand washing facility	10 (31.5)		233	68.5
Mosquito net usage	286	84.1	54	15.9
Knowledge about folic acid and iron supplementations	215	63.2	125	36.8
Reasons for using iron and Folic acid supplements	72	24.7	268	75.3
Adherence using iron and folic acid supplements	256	75.3	84	24.7

Pregnancy and Nutritional Status

Among the surveyed pregnant women, 46.5% were in their three or four and 20.58% had experienced five or more pregnancies (Table 4). Despite the increased nutritional demands associated with multiple pregnancies, the vast majority (92.06%) of women maintained a normal nutritional status suggesting that their diets, potentially rich in indigeneous vegetables may be providing adequate nutrients including iron to support maternal health. The absence of severe under-nutrition and the relatively low percent (7.94%) of moderately undernourished women suggest that iron intake through local vegetables could be playing a significant role in maintaining normal nutritional status and preventing anemia. High parity is among the factors with etiological potential in causing anemia in pregnancy[13] as it increases the physiological demands on the body particularly the

need of iron and other essential nutrients to support maternal and fetal health. Despite the heightened nutritional needs associated with parity only 27.05% of women sought antenatal care before the 12th week of the pregnancy, while 53.52% visited between the 12th and 20th weeks, and 19.41% delayed their care until after the 20th week. Early antenatal care is critical for identifying potential health risks, including anemia, and for providing dietary guidance, such as increasing iron intake. The timing of these visits is particularly important for women with higher parity, as they are more susceptible to nutritional deficiencies due to repeated pregnancies. Despite the challenges posed by parity and varying antenatal care attendance, 92.06% of women are classified as having normal nutritional status based on mid-upper arm circumference (MUAC) measurements. This suggests that many women in this population are meeting their nutritional needs. Only 7.94% of women were moderately undernourished, and none were severely undernourished. These findings underscore the importance of promoting early antenatal care and continued nutrition education on dietary intake particularly with nutrient-dense foods like indigenous vegetables, to further optimize iron intake and prevent pregnancy-related anemia in this population.

Table 4: Pregnancy information and nutrition status

Variable	Frequency (%)	
Pregnancy Frequency		
1-2	112 (32.9)	
3-4	158 (46.5)	
> 5	70 ( )	20.58
Parity		
1-2	5 ( )	1
3-4	274 ( )	81
>4	61	18
Antenatal care visit		
Below 12 weeks	92	27.05
12-20 weeks	182	53.52
Above 20 weeks	66	19.41
Nutrition status/Muac		
Moderately undernourished	27	7.94
Normal nutrition status	313	92.06
Undernourished	0	6

Social demographic Factors Related to Anemia in Pregnancy

Hemoglobin, a key protein in red blood cells, is responsible for carrying oxygen from the lungs to tissues throughout the body. During pregnancy, the body's demand for oxygen increases, placing greater strain on hemoglobin production. If hemoglobin levels fall below the normal range, the body cannot deliver adequate oxygen to vital organs, resulting in impaired function and symptoms associated with anemia. Hemoglobin level data collected from the clinic cards of the participants revealed that 45% of pregnant mothers were anemic, while 55% were not (See Table 5). It is important to note that physiologically hemoglobin needs are higher at higher altitudes due to the lower oxygen concentration in the atmosphere. The study found a significant correlation between age and the likelihood of being anemic in pregnant women ($\chi 2 = 6.43$, df = 2, $p < 0.04$), with older mothers, particularly those aged 36 to 49, exhibiting a lower risk of anemia. Younger pregnant women were more prone to anemia, which may be attributed to several factors like; inadequate nutrition is a key factor, as younger women may lack access to proper foods, such as iron and folate rich foods, essential for blood production. Additionally, adolescents and younger women are still growing, which increases the body demand for iron and other nutrients. Their rapid growth, combined with the demands of pregnancy, can result in insufficient iron stores, further contributing to anemia. In contrast, older women may benefit from more established dietary habits, greater nutritional knowledge, and better access to healthcare, allowing for more consistent management of their nutritional status. They may also have more experience with pregnancy, leading to a greater awareness of the importance of iron and folic acid intake during this critical period. These factors likely contribute to their reduced risk of anemia compared to their younger counterparts. Marital status also showed a significant association with anemia ($\chi 2 = 4.1$, df = 1, $p < 0.04$). Being married was associated with a lower likelihood of anemia, with 58% of married women in the study not being anemic. This finding aligns with previous research conducted in Nigeria, where married women or those in a marital union were found to have reduced odds of anemia compared to their single, divorced, widowed, or separated counterparts.[14] The

association between marital status and anemia can be linked to socioeconomic factors that influence health outcomes. Married women may benefit from greater emotional and financial support from their spouses, which can lead to improved nutrition and healthcare access during pregnancy.[15,16] Additionally, the stability that comes with marriage may reduce stress levels and promote healthier living conditions, contributing to lower rates of anemia.

Table 5: Association of Socio-Demographic Factors with Anemia in Pregnancy

Characteristics	Anemic (n=186)	Non-Anemic (n=154)	Chi² (χ^2)	df	P-Value
Age (years)			6.43	2	0.004
19-35	152 (81.7%)	123 (79.9%)			
36-49	34 (18.3%)	31 (20.1%)			
Marital Status			4.1	1	0.004
Married	108 (58%)	123 (79.9%)			
Cohabitating	78 (42.0%)	9 (5.9%)			
Nutritional Knowledge			7.5	1	0.006
High	55 (29.6%)	92 (59.7%)			
Low	131 (70.4%)	62 (40.3%)			
Education			5.8	2	0.02
≤ Primary	147 (78%)	105 (68.2%)			
≥ Secondary	41 (22%)	49 (31.8%)			

Table 6: Dietary diversity score DDS

Food groups	Frequency	(%)
Starch/staples	339	99.54
Dark green vegetables	135	39.69
Vitamin A fruits and vegetables	76	22.35
Other fruits and vegetables	92	27.05
Meat	43	12.64
Meat/fish	165	48.52
Eggs	158	48.52
Legumes	148	43.35
Milk and milk products	75	11.98

Source: Data from this research N=340

Dietary practices and Food Security among Pregnant Women in Babati District

A more diversified diet is associated with several improved outcomes in areas such as birth weight, child anthropometric status, and improved hemoglobin concentration levels. According to FAO (2018) protocol WDDS was calculated based on 9 food groups as shown in Table 6. The following set of 9 food groups starchy/staples, Dark green vegetables, Vitamin A fruits/vegetables, other fruits/vegetables, meat, Meat/fish, eggs, legumes, and milk and milk products were used to calculate the dietary diversity. Studies have shown that the consumption of five or more groups of food can be used as a proxy indicator for micronutrient adequacy. As per table below only 189 pregnant women out of 340 met the minimum dietary diversity which is having more than 5 food groups. The WDDS revealed that the majority of study population had a diet predominantly based on starchy staple foods with 99.54% consuming these daily. However, consumption of more nutrient-dense food groups, such as dark green vegetables (36.69%), vitamin A-rich fruits and vegetables (22.35%), and other

fruits and vegetables (27.05%), was lower. This indicates a potential risk of micronutrient deficiencies particularly in vitamins and minerals. Animal based proteins such as meat, fish, and eggs were consumed by approximately half of the population under study (48.52%), while organ meat which is rich in iron and vitamin B12 were consumed by only 12.64%. Additionally, legumes were consumed by 43.35% of the participants offering a plant-based source of protein, though their availability of nutrients such as iron and zinc is generally lower than animal-based sources. The low intake of milk and products (11.98%) is concerning, dairy products are a key of calcium, essential for bone health and growth particularly in children. This suggests a potential risk of calcium deficiency in the population. The general low intake of foods high in nutrients and the reliance on staples suggest a diet that may be energy-sufficient but low in nutrients, with potential health effects on the general people, particularly in relation to iron, calcium, and vitamin A shortages.

Table 7: Frequently used mixtures

Variable	N	Percentage (%)
Sweet potatoes leaves+ amaranth with lemon	138	40.58
Black jack + baobab powder	59	17.35
Roselle soaked overnight+ baobab	33	9.71
Amaranth and African night shade	17	5
Bitter lettuce + Amaranth	5	1.47
African spider flower +amaranth	3	0.88
	85	25

Local Mixtures used for Prevention and Management of Anemia during Pregnancy

Table 7 provides an insightful overview of the frequently used mixtures among the surveyed participants for the alleviation of anemia symptoms. The table shows various combinations of locally available ingredients and their respective frequencies of use, represented both in raw frequency counts and as percentages. The most prevalent mixture reported by 138 (40.4%) of the respondents was a combination of sweet potato leaves and amaranth complemented with lemon juice. This blend was followed by a mixture of blackjack leaves combined with baobab powder, reported by 59 (17.4%), indicating a preference for this combination among the surveyed population. Moreover, the utilization of rozella soaked overnight with baobab was another combination mentioned by 33 (9.7 %) of the respondents. Others were a combination of amaranth with African nightshade, bitter lettuce with amaranth, and African spider flower with amaranth at a composition 17(5%), 5 (1.5%), and 3 (0.9%) respectively.

Discussion

Iron is essential for the structure and function of red blood cells and its deficiency leads to anemia, a prevalent health concern in many developing countries. African indigenous vegetables, which are rich in iron, can help alleviate this problem by providing sufficient iron to meet daily nutritional needs. Our findings highlight the prevalence of pregnancy related anemia and emphasize the potential of indigenous vegetables to improve iron intake, which could help mitigate the risk of anemia among pregnant women. In this section, it is crucial to acknowledge the limitations of the cross-sectional design in establishing causality. The study being cross-sectional measures both the exposure (consumption of indigeneous vegetables) and the outcome (prevalence of anemia) at a single point in time which makes it impossible to infer directionality. The cross-sectional design restricts our ability to draw firm conclusions about the causal relationship between vegetable consumption and anemia prevention. Despite these limitations, we controlled for potential confounders such as parity, gestational age, and socioeconomic status by collecting comprehensive data on these factors, including household income, educational attainment, and dietary diversity scores. Multivariable logistic regression was used to adjust for these confounders, strengthening the validity of the observed associations. Our findings suggest a significant

association between factors like poverty and hygiene practices and the prevalence of anemia, which warrants further investigation. For instance, the presence of shared sanitation facilities was linked to an increased risk of infectious diseases, which could contribute to anemia. This emphasizes the need for a multi-pronged strategy that not only targets dietary interventions but also addresses the cyclical relationship between infectious diseases, inflammation, and nutritional status. Improved hygiene practices play a crucial role in enhancing iron absorption and reducing the risk of anemia by preventing infections that disrupt gut health. Poor sanitation and inadequate handwashing increase exposure to pathogens, leading to gastrointestinal infections that cause chronic inflammation, gut dysbiosis, and reduced nutrient absorption. The gut microbiome is essential for iron solubility and uptake, with beneficial bacteria such as Lactobacillus plantarum and Bifidobacterium longum improving iron bioavailability by modulating gut pH and reducing inflammation. However, dysbiosis caused by infections, poor diet, or antibiotic overuse can favor pathogenic bacteria like Salmonella, which compete for iron and reduce its absorption. By promoting proper sanitation, access to clean water, and improved hygiene education, the risk of recurrent infections can be minimized, thereby preserving gut integrity and enhancing iron absorption, ultimately reducing anemia prevalence. As previous studies have shown, hookworm infestations and other parasites in the intestines are strongly linked to anemia, particularly in schoolchildren. Inflammation is also recognized as a critical factor contributing to anemia, especially among adolescents.[17-19] Additionally, inflammation is recognized as a critical factor contributing to anemia among school going adolescents.[20] In our study, we found a significant association between hygiene practices and reduced the risk of iron deficiency anemia. The accesses to private sanitation facilities, treated water, and overall household wealth as proxies for living conditions were all associated with lower rates of anemia.[21] A study by Molla indicated that improved access to sanitation reduces anemia risk among women of childbearing age in southern Africa, and access to clean water is linked to better nutritional outcomes in preschool children in Ethiopia.[18] The role of hygienic practices cannot be overlooked in the observed relationship between shared toilet use and anemia among adolescents. It is not the act of sharing toilet itself that directly contributes to anemia but rather increased risk of poor hygiene associated with shared facilities.[22] For instance, inadequate hand washing practices after using shared toilets can lead to the spread of infections, such as gastrointestinal diseases, which may cause chronic diarrhea. This, in turn, can impair nutrient absorption, leading to deficiencies in essential nutrients like iron, ultimately contributing to anemia. Emphasizing the interconnectedness of hygiene and nutritional health highlights the need for improved sanitation and hygiene education as a strategy to combat anemia in adolescents. In terms of malaria prevention, an impressive 86% of pregnant women in our study owned mosquito nets, and 84% actively used them. Malaria is a well-known contributor to anemia during pregnancy; therefore, this high level of mosquito net usage likely mitigates one of the significant risk factors for anemia in this population. The interplay between malaria and anemia is particularly significant in regions where malaria is endemic. Anemia is often exacerbated by malaria infections, which lead to the destruction of red blood cells and impaired erythropoiesis (the production of new blood cells).[23] This relationship is further complicated by other infectious diseases and nutritional deficiencies that frequently occur in affected populations. For instance, in areas with moderate to high malaria transmission, severe anemia is linked to bacterial infections, HIV, and nutritional deficiencies such as vitamin A and B12.[24] Infectious diseases trigger systemic inflammation, leading to increased production of hepcidin, a hormone that regulates iron metabolism by inhibiting intestinal absorption and iron release from body stores, ultimately reducing iron bioavailability. Malaria exacerbates anemia through red blood cell destruction,[25] while hookworm infections contribute to chronic blood loss, further depleting iron levels. Chronic inflammation not only disrupts iron metabolism but also impairs the absorption and utilization of essential micronutrients such as zinc, vitamin A, and folate due to cytokine-induced gut permeability changes and oxidative stress.[26] The gut microbiome plays a crucial role in modulating these interactions, as beneficial bacteria like Lactobacillus and Bifidobacterium enhance iron solubility and absorption, whereas pathogenic bacteria compete for iron, worsening deficiency. Dysbiosis caused by infections, poor diet, or antibiotic use further

exacerbates nutrient deficiencies and systemic inflammation. Strategies such as malaria prevention, deworming programs, iron and folic acid supplementation, and microbiome-targeted interventions like probiotics and prebiotics can help mitigate anemia risk by improving gut health, reducing inflammation, and enhancing nutrient absorption. Understanding these interconnected factors is essential for developing effective, multifaceted interventions to combat anemia in high-risk populations. These coexisting conditions not only contribute to the development of anemia but also complicate its management and treatment. The influence of marital status in anemia prevalence significantly influences anemia prevalence as observed in the study. This observation aligns with previous study conducted in Nigeria found out that married women or those in marital unions exhibited reduced odds of being anaemic compared to their single, divorced, widowed, and separated counterparts.[27] This relationship can be attributed to various socioeconomic factors that significantly influence health outcomes. Married women experience greater emotional and financial support from their spouses, enhancing their access to nutritious food and healthcare during pregnancy. Furthermore, the stability that often accompanies marriage can help reduce stress levels, promoting healthier living conditions and contributing to lower rates of anemia. Moreover, this study found that socioeconomic factors such as educational level, marital status and nutritional knowledge are associated with IDA. A study among Korean adolescent girls, found that those with lower socioeconomic status had a higher prevalence of anemia and iron deficiency anemia.[28] A plausible explanation for the lower prevalence of IDA among individuals from higher-income households is their ability to afford iron-rich foods, such as red meat which are critical for preventing anemia and maintaining healthy iron levels.[29] Our results show an intersection of hygiene, health, social support, and nutrition in causing and therefore possible prevention of IDA. Additionally, there is a relationship between dietary diversity and iron deficiency anemia in that a higher dietary diversity score (DDS) increases the intake of iron-rich foods such as meat, fish, eggs, and legumes, which are critical sources of bioavailable iron.[30] However, as reflected in Table 6, the low consumption of iron-rich food groups like meat (12.64%) and milk products (11.98%) suggests dietary inadequacies that may contribute to the high prevalence of iron deficiency anemia. A diverse diet plays a crucial role in maintaining the immune system, which acts as the body first line of defense against harmful pathogens and oxidative stress. The immune system relies on an intricate network of cells and tissues, and factors such as diet, rest, and stress levels are essential for its proper functioning.[31] The study highlights the complex relationships between dietary practices and anemia prevalence. In younger women anemia is often to iron deficiency due to menstrual blood loss, increased iron requirements during pregnancy and insufficient dietary intake. As women age changes in blood metabolism and blood volume occur influencing anemia risk.[31,32] Iron deficiency persists even beyond the reproductive years and although menopause reduces iron loss due to cessation of menstruation, iron stores can still remain low, exacerbating anemia risks if not adequately addressed.[33-35] This underscores the importance of considering not only dietary factors but also biological and age-related mechanisms when assessing anemia prevalence across different populations.

In order to empower maternal health in the Babati District and nationally interventions should be holistic, considering not only nutritional aspects but also social and economic factors. The recognition of the complex interplay between age, marital status, and anemia emphasizes the need for tailored approaches that account for diverse demographic profiles. The linear optimization technique is a widely used method for food formulation, aimed at creating a cost-effective yet nutritionally rich diet.[36-39] This approach enables the optimization of nutritional requirements for specific age groups or individuals with special dietary needs. These findings are in line with prior studies[40-42] which emphasized the applicability of linear programming techniques in formulating cost-efficient diets that meet daily nutritional requirements. However, it is important to note that the formulated diet is not intended as an ideal solution for pregnant women, but rather as a means to optimize costs and ensure nutritional adequacy, especially for pregnant women with limited dietary iron and vitamin C intake, particularly in rural areas of developing countries

Conclusion

The study highlights the nutritional significance in mitigating pregnancy related anemia among women in Babati, Tanzania. The incorporation of iron-rich and vitamin C rich vegetables, such as amaranth, blackjack, baobab, and sweet potato leaves, demonstrates a viable solution for enhancing iron intake in pregnant women. Notably, blackjack, when consumed raw, retains its high iron content, while vitamin C-rich options like baobab enhance iron absorption from plant-based sources, making these vegetables particularly effective in addressing anemia. The findings emphasize that these locally available vegetables when combined with proper dietary practices offer an accessible and culturally appropriate means of improving maternal nutrition and preventing anemia. Through dietary diversity and the inclusion of iron enhancing foods, pregnant women can achieve better iron absorption and reduce risk of anemia. The study also revealed a strong association between hygiene practices specifically hand washing and a reduced risk of anemia highlighting the importance of holistic approaches to maternal health. While the study shows promise, further research is needed to explore the seasonal availability of these vegetables and the long-term impact of their consumption on anemia prevention. Future public health interventions should integrate nutrition education, emphasizing the use of indigenous vegetables to foster sustainable dietary habits among pregnant women in rural areas. To confirm the role of these foods in ensuring a healthy pregnancy, it would be valuable to assess anemia status both at the beginning and end of pregnancy. While the study shows promise, further research is needed to explore the seasonal availability of these vegetables and the long-term impact of their consumption on anemia prevention. Future public health interventions should integrate nutrition education, emphasizing the use of indigenous vegetables to foster sustainable dietary habits among pregnant women in rural areas.

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1. **Zuwena Abbass Malley:** Conceptualization, Methodology, Data Analysis, Writing–Original Draft.
2. **Elingarami Sauli:** Visualization, Supervision, Project Administration.
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