LEVERAGING INDIGENOUS VEGETABLES TO COMBAT ANAEMIA AMONG PREGNANT WOMEN IN BABATI

Zuwena A. Malley

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Human Nutrition and Dietetics of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

August, 2025

ABSTRACT

Pregnancy related anaemia remains a significant public health concern in Tanzania particularly among women of reproductive age. Limited dietary iron intake is a major contributing factor, despite the availability of iron supplements. However, poor adherence to supplementation due to side effects, limited access, and inadequate health education has hindered efforts to address the problem. The study investigated the potential of indigenous vegetables as a dietary intervention to prevent and manage anaemia among pregnant women in Babati District, Manyara region. A cross-sectional study was conducted from June to August 2023 involving 340 pregnant women attending antenatal clinics at four health facilities in Babati District. Nutritional analysis was conducted on commonly consumed indigenous vegetables to assess their iron, vitamin C and phytate content. The findings revealed that indigenous vegetables such as amaranth, sweet potatoes leaves and blackjack are rich in iron and culturally accepted and locally accessible. However, their consumption was irregular due to limited awareness, seasonal availability and preferred for exotic vegetables. The study also found a significant association between frequent consumption of indigenous vegetables and higher haemoglobin levels among pregnant women. Respondents who consumed these vegetables at least three times a week had a lower prevalence of anaemia compared to those who consumed less frequently. Promotion of regular consumption of iron rich indigenous vegetables could serve as an effective, affordable, and culturally appropriate dietary strategy to reduce anaemia in pregnancy. The community nutrition education and support for local vegetable cultivation is recommended to enhance dietary diversity and maternal health outcomes.

DECLARATION

I, Zuwena A. Malley, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor concurrently submitted for a degree or similar award in any other institution.

Zuwena A. Malley **Date**

The above declaration is confirmed by:

Dr. Haikael D. Martin Date

Dr. Elingarami Nkya Date

COPYRIGHT

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance and approval by the Senate of the Nelson Mandela African Institution of Science and Technology the dissertation entitled "*Leveraging indigenous vegetables to combat anaemia among pregnant women in Babati*." in partial fulfilment of the requirements for the Award of the Degree of Master of Science in Human Nutrition and Dietetics of the Nelson Mandela African Institution of Science and Technology, Arusha Tanzania.

Dr. Haikael D. Martin Date

Dr. Elingarami Nkya Date

ACKNOWLEDGMENTS

First and foremost, I extend my gratitude to Allah for the mercy and grace that empowered me to successfully pursue my studies. I also wish to convey my sincere appreciation to my supervisors, Dr. Haikael D. Martin and Dr. Elingarami Nkya, for their unwavering guidance and mentorship throughout my Master's research journey. Their support provided me with intellectual freedom, encouraged the exploration of new ideas, and demanded a high standard of excellence in all my endeavors, contributing significantly to a fulfilling graduate school experience.

Also, I would like to acknowledge my work place Meatu District council for the permission and support during my studies. Furthermore, I would like to express my gratitude to health facilities workers, research assistant Mr. Kelvin Vulla and participants for their tireless collaboration and substantial contributions to this study.

Finally, I want to recognize and appreciate my family and friends for their constant love and support

DEDICATION

This work is dedicated to the Almighty God (Allah S. A. W) for His protection and guidance during my academic life. It is also dedicated to my lovely mother (Mrs. Shafia Juma Mlumba) for her support throughout my studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

IDA	Iron Deficiency anaemia
NMNAP II	National Multisectoral Nutrition Action Plan II
KRA	Key Result Area
RCHC	Reproductive and Child Health Clinic
HF	Healthcare facilities
HC	Health Centers
FEFO	Iron and Folic Acid
WHO	World Health Organization
DC	District Council
TC	Town council
RDA	Recommended Dietary allowance
IVs	Indigenous vegetables
TNNS	Tanzania National Nutrition Survey
DDS	Dietary Diversity Score
DRI	Dietary Recommended Intake
DRV	Dietary Recommended Value
FAO	Food and Agriculture Organization of the United Nations
IU	International Unit
DRNI	Daily Recommended Nutrient Intakes
RDI	Reference Dietary Intake

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Anaemia affects women differently depending on their socioeconomic level, lifestyle, or approach to seeking health care. The prevalence rates of anaemia in developing countries is higher than in developed nations accounting 43% and 9%, respectively (Kinyoki *et al.,* 2021; Sunguya *et al.,* 2021). Anaemia affects all groups of people with pregnant women and children being more vulnerable. Pregnant women have an increase demand for iron in order to expand their erythrocyte mass and fulfill the iron needs of the growing fetus (Milman *et al.,* 2005).

During pregnancy the amount of absorbed iron that is needed rises from roughly 1.0 mg per day in the first trimester to 7.5 mg per day in the third trimester (Brannon & Taylor, 2017; Fisher & Nemeth, 2017). Mostly pregnant women in Tanzania have low blood iron levels before becoming pregnant, which is made worse by the fetus' increased requirement for iron (Azhar *et al*., 2021). Iron deficiency and iron deficiency anaemia during pregnancy pose inherent risks including inherent risks, preterm birth, and low birth weight for gestational (Costanza *et al*., 2021).

Moreover, anaemia is associated with detrimental effects on the baby cognitive and emotional development (Lozoff, 2007; Walter, 1994). It is widely recognized as a significant risk factor for poor pregnancy outcome leading to life threatening complications for both mothers and fetus. Iron deficiency is responsible for the majority of anaemia cases making it the most widespread nutritional disorder globally (Shi *et al*., 2022). In Tanzania, the prevalence of anaemia among women of reproductive age (15-49 years), defined as a hemoglobin concentration of less than 11 g/Dl, was 42% according to the Tanzania Demographic and Health Survey (TDHS) 2022 an increase from the previously recorded 40% prevalence in 2010 (Yusufu *et al*., 2023). This rising trend highlights the urgent need for effective interventions to combat iron deficiency, particularly among pregnant women.

The World Health Organization recommends a daily intake of 30-60 mg of iron and 400 µg of folic acid in preventing anaemia in newborns (Stoffel *et al.,* 2020). Daily iron supplementation is widely recommended for pregnant women due to benefits but is faced by side effects such as nausea, constipation and abdominal discomfort resulting into poor adherence to supplementation regiments (Benson *et al*., 2022; O'Toole *et al.,* 2024). Iron absorption can also

be negatively affected by dietary inhibitors such as phytates found in plant based issues like infections and chronic inflammation (Zijp & Tijburg, 2000). Furthermore, monitoring iron levels and ensuring compliance can be difficult, especially in areas with limited healthcare infrastructure.

These challenges necessitate the need for comprehensive strategies that combine education, improved healthcare access, and dietary support alongside supplementary efforts. Instead of depending on iron or micronutrient supplementations food can be a great source of iron, some of the foods that are rich in iron are meat, especially organ meat and green leafy vegetables (Buzigi & Siwela, 2020). Moreover, vegetables can provide adequate amount of iron if consumed at recommended amount, it can provide optimum amount of iron required during pregnancy which is 27 mg/day RDA (Recommended Dietary allowance) (Milman, 2020). Iron is a key component of hemoglobin responsible for oxygen transport in the blood. Iron rich foods include dark green leafy vegetables like spinach and collard greens, artichokes, blackstrap molasses, tofu, quinoa and prunes (Caplan, 2007).

Vegetables include two types which are cultivated and non-cultivated or indigenous. Native vegetable species or types that are not used in local people's cropping systems are referred to as non-cultivated indigenous vegetables (IVs) (Msuya *et al*., 2009). These locally grown vegetables are well known for being locally accessible and affordable. The situation calls for an innovative way of reducing the risks of iron deficiency anaemia by ensuring enough iron consumption among pregnant women of reproductive age. The objective of this study was to investigate dietary habits of women in Babati and their association with anaemia and social demographic factors.

1.2 Statement of the Problem

Despite the provision of free iron supplements to pregnant women at all antenatal clinics in Tanzania, pregnancy related anaemia remains prevalent at high scale. For instance, in the Manyara region, the prevalence is 32.7% with the conditions being more common among households with lower socioeconomic status (TNNS survey, 2018, 2019). At the national level, only 28.5% of women aged 15-49% adequately used the iron supplementation for 90 days during pregnancy (TNNS, 2018). While in Manyara region only 21.2% took iron and folic acid supplements for 90 days or longer during their last pregnancy (TNNS-2018).

This poor compliance contributes to the persistence of anaemia during pregnancy, which in

turn is a leading cause of maternal deaths hindering the country efforts to reduce maternal mortality rates. While iron supplementation is widely available side effects such as gastrointestinal discomfort, bloating, nausea and vomiting contributes to poor adherence. In some communities, pregnant women turn to locally available decoctions to manage or prevent anaemia. Furthermore, limited nutrition education among healthcare providers and community regarding iron rich foods and appropriate intake during pregnancy exacerbates the issue. Indigenous vegetables such as African spider flower, bitter lettuce and amaranth are to known to be rich in iron and other essential micronutrients remain underutilized due to insufficient promotion and awareness. Given these challenges, there is a pressing need to analyze the composition and efficacy of locally available decoctions in Babati in order to inform evidence-based strategies for the prevention and management of anaemia during pregnancy.

1.3 Rationale of the Study

Pregnancy related anaemia remains a major public health concern in Tanzania despite the widespread availability of iron supplementation programs. While iron supplements are effective their usage is often hindered by poor adherence due to gastrointestinal side effects, accessibility challenges, and socio-cultural barriers. Consequently, many pregnant women fail to meet their daily iron requirements increasing the risk of maternal and neonatal complications. This study aims to address this persistent issue by exploring the potential of indigenous vegetables as a sustainable, locally available and nutrient-rich source of iron. Unlike synthetic supplements, indigenous vegetables are culturally accepted, affordable and easily accessible, making them a viable long-term strategy for improving iron intake. By assessing dietary habits and their association with anaemia among women in Babati, this study will provide valuable insights into how indigenous vegetables can be optimized as a dietary intervention to reduce iron deficiency anaemia.

1.4 Research Objectives

1.4.1 General Objective

To assess the use of indigenous vegetables among pregnant women in Babati in combating and preventing anaemia.

1.4.2 Specific Objectives

(i) To assess types of indigenous vegetables commonly used by pregnant women to

prevent and manage anaemia.

(ii) To analyze phytate, iron and vitamin C contents in indigeneous vegetables used to prevent anaemia in pregnancy.

1.5 Research Questions

(i) What are the types of indigenous vegetables commonly used by pregnant women to prevent and manage anaemia?

(ii) What are the phytate, vitamic C, and iron contents of indigenous vegetables used to prevent anaemia in pregnancy?

1.6 Significance of the Study

This study has a potential to provide a practical and sustainable solution for managing and preventing anaemia during pregnancy. The study is expected to provide:

Promotion for the use of locally available, nutrient-rich indigenous vegetables to combat anaemia offering an affordable and sustainable alternative to iron supplements particularly in resource-limited settings as addressed in SDG 12.

To raise awareness among communities and healthcare providers about the benefits of indigenous vegetables as natural dietary interventions for anaemia leading to long term health benefits.

1.7 Delineation of the Study

The study is delimited to evaluating how indigenous, locally available vegetables contribute to reducing iron deficiency anaemia among pregnant women in Babati district. The study focus on analyzing the iron and vitamin C content of commonly consumed indigenous vegetables and examining dietary habits of pregnant women in relation to these foods. The study does not explore medical intervention, iron supplementation, or anaemia related health outcomes in Babati region and doesn't explore development or clinical testing of any new nutritional formula or supplements. The research maintains a clear focus on food based, culturally relevant approaches to improving maternal iron intake. The findings are expected to inform the community nutrition education, guide local health policies and support future research on the role of indigenous foods in maternal health.

CHAPTER TWO

LITERATURE REVIEW

2.1 Pregnancy Induced Anaemia

Recent estimates indicate that approximately 40% of pregnant women aged between 15-49 years are affected by anaemia, with nearly half of these cases classified as moderate to severe (Pasricha & Moir-Meyer, 2023). This condition poses a significant public health challenge, particularly in developing countries as it can lead to increased morbidity and mortality rates to pregnant women and their expected newborns (Stevens *et al*., 2022). In 2022, children under 5 years old (42%) particularly newborns and young children under 2 years old, women of reproductive age (39%) and pregnant women (42%) were categorized as the most vulnerable for anaemia (Sun *et al.,* 2021).

In all age categories and across all geographic regions, women consistently had a higher risk of anaemia than men did (Chaparro *et al*., 2019). Prevalence of anaemia among women in sub Saharan Africa was 42.17% in 2021 (Gebrie *et al*., 2022). One of the top five factors contributing to maternal morbidity and mortality in Tanzania is anaemia during pregnancy. Tanzania Demographic and Health Survey projected Tanzania's maternal death rate to be 454 cases out 100 000 live births in 2010-2011 and 432 cases out of 100 000 live births in 2015-16. In Manyara region the prevalence of anaemia was higher than the national average at 54.1%, according to the Tanzania population health survey-Malaria indicator (2022) (Moshi, 2020).

This survey found that 45% of women aged 15 to 49 had anaemia. The prevalence of anaemia among women of reproductive age is currently 28.8% nationwide and 32.7% in Manyara, according to the Tanzania National Nutrition Survey, 2018. More efforts are required to meet the Five Year Development Plan III 2021/22-2025/26 goal of reducing anaemia in pregnancy by up to 22% (URT). National Multisectoral Nutrition Action Plan II 2021/22-2025/26 as per Key result area number two in reduction of micronutrients deficiency it aims to reduce anaemia from 28.8%-23%.

2.2 Risk Factors Associated with Anaemia in Pregnancy

One of the risk factors for pregnant women iron deficiency and a major causative of anaemia in pregnancy is poverty (Liyew *et al*., 2021). However results from multivariate analysis showed that anaemia was strongly and independently correlated with household monthly

income, residence, parity, access to latrines, iron supplementation and nutritional status (Lebso *et al*., 2017). Additionally, pregnant women in rural areas have less or no access to nutrition education and counseling and are more likely to be impacted by local views toward inappropriate food habits (Kaunda *et al*., 2021). Rural and urban communities generally experience disparities in women health outcomes as a result of unequal resource distribution (Sunuwar *et al*., 2019).

A study by Lin *et al*. (2018) reported that statistically significant link has been found in maternal anaemia and a lack of toilets in the home. Open defecation significantly led to the contamination of the home environment and raises the risk of getting numerous intestinal parasite infections, especially in highly populated places. Parasite infections are among the most common causes of nutrient malabsorption, appetite loss and elevated blood loss, which decrease hemoglobin concentration (Liyew *et al*., 2021). In Africa, two thirds of women who are pregnant suffer from anaemia brought on by hookworm. Therefore, increased cleanliness and hygiene are essential to reducing the risk of anaemia, which mainly function by lowering the probability of recurrent intestinal parasite infestation (Derso *et al*., 2017).

Existing literatures suggests an increase in anaemia in domestic and unemployed mothers due to sole dependence of the income from their husbands. Large percentage have low socioeconomic status, which has been identified as a known risk factor for anaemia (Obai *et al*., 2016). Compared to their counterparts, women with a secondary or higher education were less likely to be anemic. The risk of anaemia is reduced by education, according to numerous researches. Because educated pregnant women earn more money and consume a greater variety of nutritious meals, they do not get nutritional anaemia (Stephen *et al*., 2018).

Gestational age was the other factor that significantly correlated with anaemia. Women were 3.09 and 3.68 times more likely to be anemic in the second and third trimesters than in the first, respectively (Nti *et al*., 2021). Comparable research carried out in several regions of Ethiopia revealed that the risk of women acquiring anaemia increased from the first trimester to the second and third trimesters (Derso *et al*., 2017). But when compared to women who lived in small households those who lived in large families with more than five people had a higher prevalence of iron deficiency anaemia (Liyew *et al*., 2021).

Globally, approximately two billion people suffer from anaemia with about 60 million being pregnant. Anaemia is estimated to affect about 800 women and children worldwide (Derso *et al*., 2017). Pregnant women are more vulnerable due to the increased demand for iron

metabolism. Anaemia among pregnant women is a significant health problem in low-income countries, according to the World Health Organization (WHO, 2020). Anaemia is prevalent in Africa at 57.1%, with Sub-Saharan Africa at 56.0%, compared to 22% in high-income countries. However, previous Tanzanian studies have revealed a wide range of anaemia prevalence during pregnancy, ranging from 18.0% to 68.0%. Other African countries, such as Ethiopia and Ghana, have anaemia rates of 41.0% and 45.0%, respectively (Derso *et al*., 2017). According to study, Tanzania has a higher prevalence of anaemia among pregnant women, with rates of 68% in Dar es Salaam and 47% in Moshi (Stephen *et al*., 2018).

The government has improved its antenatal services over time, and all expectant mothers are now given iron supplements to prevent anaemia, deworming, malaria prophylaxis and mosquito nets. To boost medication intake, pregnant women must take a deworming drug and receive a malaria prophylaxis in front of a healthcare professional (Ngimbudzi *et al*., 2021).

2.3 Iron Rich Indigenous Vegetables for Anemia Reduction

Native vegetable species or varieties that are not grown but are not a part of the local population cropping system are referred to as non-cultivated indigenous vegetables (Msuya *et al*., 2009). In Tanzania, it is common knowledge that many non-cultivated indigenous vegetables are taken from the wild. However, there is a broad perception that their use is decreasing (Gowele *et al*., 2019). The decline of these species can be attributed to their inability to compete with cultivates vegetables particularly exotic varieties as well as their negative perception as low status food items especially in urban areas. Therefore, further work is needed to increase acceptance of these vegetables and their uses in reducing anaemia (Gowele *et al*., 2019). Study conducted by Msuya *et al*. (2009), shows these indigenous vegetables has high content of iron one of which being African spider flower and bitter lettuce which has iron content of up to 49.9 mg per 100 g edible portion.

In Tanzania, micronutrient dietary deficits that result in nutrition problems like anaemia are still prevalent (Gowele *et al*., 2019). It is crucial to find and use rich sources of these nutrients in order to address the nutritional anaemia issue. These native vegetables have a considerable chance of lowering the undetected deficiency brought on by lack of certain micronutrients (Bhatnagar & Padilla-zakour, 2021). Furthermore, care is required to consider the aspects of nutrient bioavailability and retention with respect to cooking methods when consuming these vegetables (Msuya *et al*., 2009). The World Health Report of 2002 revealed that, diets that lack fruit and vegetable components are responsible for about 31% of ischemic heart disease and

11% of stroke globally. Generally, it is projected that, if fruits and vegetable consumption increases substantially, up to 2.7 million lives may be saved each year (Mtenga & Ripanda, 2022). Given the critical role of fruits and vegetables in promoting health there is a growing interest in incorporating indigenous species into diets, particularly in rural communities.

Blackjack plants have emerged as a staple indigenous vegetable, growing as weeds or can be easily cultivated in home gardens, presenting opportunities for local consumption. As a prominent African indigenous vegetable, blackjack is rich in nutrients, is easily accessible in the environment, and affordable for disadvantaged populations. Packed with essential minerals and vitamins, its consumption aligns with global health initiatives such as those advocated by the World Health Organization (WHO), urging increased intake of fruits and vegetables in African nations (Organization, 2003). Consequently, blackjack is widely embraced as an edible vegetable across various regions, where it forms a regular part of the diet (Mtenga & Ripanda, 2022).

Sweet potato (*Ipomoea batatas*) holds significance as a primary food crop on a global scale, prominently cultivated and enjoyed across East Asia and Sub-Saharan Africa. Notably, China leads in sweet potato production, contributing a substantial 76.07% to the world's output. Sweet potato leaves (SPL) are valued as a leafy vegetable consumed by humans, appreciated for its abundant yield, resilience to drought, and adaptability to diverse climates and agricultural methods (Nguyen *et al*., 2021).

Amaranthus Spp. comprise a diverse group of food crops encompassing 60 species. Among these, three species are cultivated for their edible grains, while 17 species are cultivated for their edible leaves (Achigan-Dako *et al*., 2014). The leaves of Amaranthus find culinary utility across many African nations, where they are incorporated into various dishes such as infusions, salads, soups, sauces and mixed with other vegetables or legumes (Achigan-Dako *et al*., 2014). They are widely regarded as the most commonly harvested and consumed African leafy vegetable, Amaranthus leaves are prized for their affordability and abundant reserves of minerals and vitamin C (Odhav *et al*., 2007; Van Jaarsveld *et al*., 2014).

2.4 Iron Availability in Indigenous Vegetables

Bioavailability of nutrients is a proportion of nutrients in food that is utilized for normal body function. The human body needs micronutrients, such as vitamins and minerals, in modest amounts to sustain maximum health and function (Msuya *et al*., 2009). One such micronutrient

is iron, which carries out a number of essential biological processes, including DNA synthesis, immunological response, cofactor for enzymes, synthesis of neurotransmitters, oxidation/reduction reactions, and other metabolic processes. The oxygen-transporting proteins hemoglobin and myoglobin need iron to be produced (Bhatnagar *et al*., 2021).

Hemoglobin levels drop due to iron deficiency, which has a negative impact on health. Iron deficiency is a major global health issue that is largely caused by poor iron absorption from the diet (Ngimbudzi *et al*., 2021). Several dietary factors may have an impact on this uptake like calcium and plant-based substances in vegetables, tea, and coffee (such as polyphones, phytates). People with low heme iron consumption, low enhancing factor intake, and high inhibitor intake may have trouble absorbing iron (Piskin, Cianciosi, Gulec, Tomas & Capanoglu, 2022). While there is an increase in iron absorption when iron reserves are low, this effect is insufficient to make up for the suppression of iron absorption under such unfavorable dietary condition (Neufingerl *et al*., 2022).

Spices and herbs are widely used in indigenous diets in tropical regions where iron deficiency is still prevalent. They are high in polyphenolic compounds, which are thought to inhibit iron absorption by forming iron complexes in the intestine, thereby reducing the availability of dietary iron for absorption. The bioavailability of iron derived from plants is lowered by the presence of intrinsic factors that influence absorption. Additionally, consuming additional meals that impede absorption can reduce the bioavailability of iron from plants. While a typical meal may contain a number of iron promoters and inhibitors, determining how these interactions will ultimately affect iron bioavailability can be difficult (Bhatnagar *et al*., 2021).

Iron exists in two forms which the oxidized ferric form and the reduced ferrous form. For iron to be effectively absorbed in the human intestine, it must be in the ferrous state (Piskin *et al*., 2022). Various to note that phytate only affect non-heme iron which is the type of iron found in plant sources. In contrast, calcium is another inhibitor that affects the absorption of heme (from animal sources) and non-heme iron. This dual inhibition makes calcium a broader dietary factor to consider when addressing iron deficiency, especially in populations with high calcium intake. Understanding these interactions are crucial for developing effective dietary strategies to improve iron status particularly in individuals at risk of iron deficiency anaemia.

2.5 Micronutrient Deficiency and Risk of Adverse Pregnancy Outcome

Micronutrient deficiencies exert a significant influence on the economic advancement of both

communities and nations. Such insufficiencies can result in severe health complications, encompassing diminished resistance to infectious ailments, vision impairment, fatigue, impaired learning abilities, cognitive delays, depletion of human capital and productivity and, in extreme cases, mortality (Ekweagwu *et al*., 2008).

Due to its harmful consequences on the mother and developing foetus during pregnancy, anaemia has gained attention on a global scale. According to some study, preterm birth, hypertensive issues and low birth weight are all associated with an increased risk of adverse pregnancy outcomes (Obai *et al*., 2016). Unfavorable pregnancy outcomes of anaemia have been reported to include preterm labor and low birth weight (Lin *et al*., 2018). Postpartum hemorrhage has been linked to a number of placental or delivery-related disorders, including placental abruption (Azhar *et al*., 2021). Placental abruption is also linked to preterm birth. Independent of the severity level, pregnant women with anaemia were more likely to experience these negative effects than pregnant women with normal hemoglobin levels. But it was discovered a reverse J-shaped relationship between the level of anaemia during pregnancy and other negative outcomes, like shock and ICU admission, with the lowest risk among pregnant women with moderate anaemia.

2.6 List of Key Variables

For the survey on indigenous vegetables and their role in preventing and managing anaemia during pregnancy, various variables were included in the data collection instrument to align with the research objectives. The questionnaire was structured on dietary practices, nutritional knowledge, and socio-demographic characteristics relevant to the consumption of indigenous vegetables. Independent variables included the frequency and type of indigenous vegetable consumption, use of herbal decoctions and overall dietary diversity. Nutrient components of interest particularly iron, vitamin C, and phytate levels were selected due to their known influence on iron bioavailability. Socio-demographic factors such as age, education level, income, marital status and house hold size were recorded to understand patterns of use. Nutritional knowledge focused on awareness of anaemia, knowledge of iron-rich foods, and awareness of supplementary during pregnancy. Hygiene and infection control practices such as the availability and use of toilets, frequency of hand washing, and use of mosquito nets were also included as background variables given their indirect influence on anaemia risk (Table 1).

Table 1: Classification of study variables by type and corresponding variables used in the analysis

Variable Type	Variable
Dependent Variable	Anaemia status (Composite: self-reported anaemia during pregnancy OR clinical pallor on ANC card (Yes/No). Also present component variables separately)
Independent Variables	Dietary intake, DDS, socio-demographics, hygiene, nutrition knowledge
Control Variables	Parity, gestational age, pre-existing conditions

2.7 Conceptual Framework

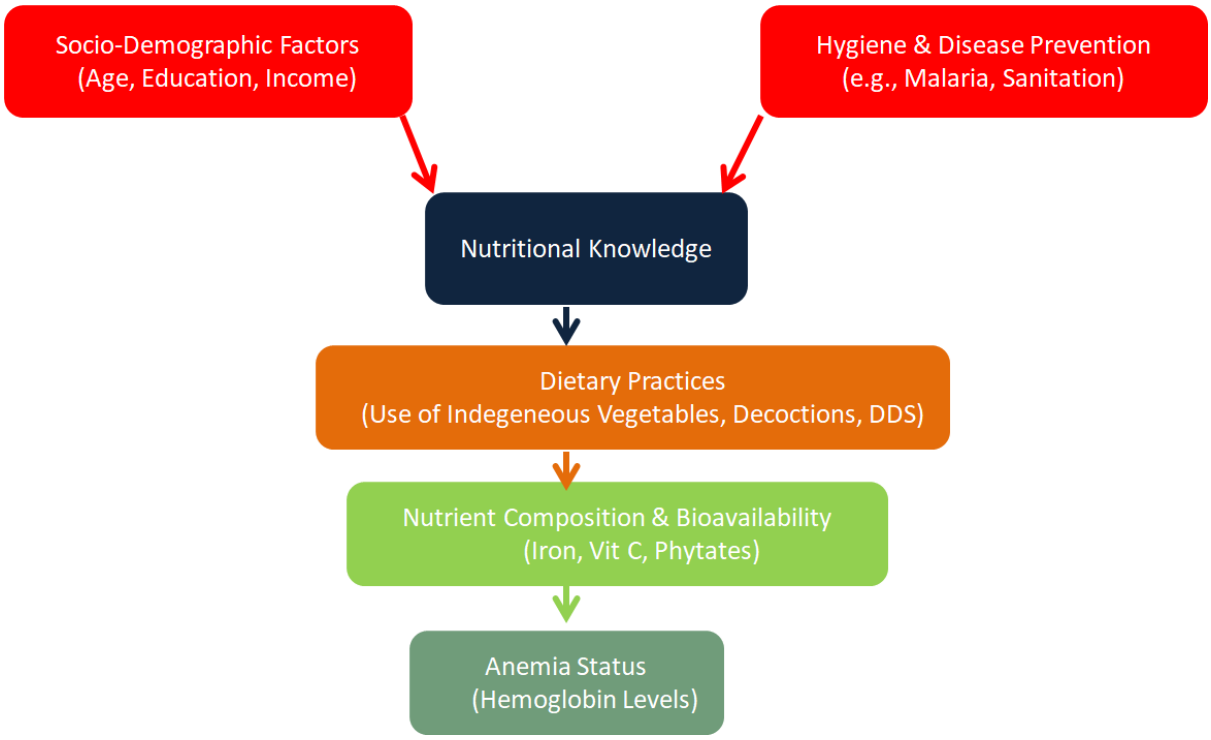

Figure 1: Conceptual Framework Showing the Relationship between Dietary Practices, Nutritional Knowledge, Socio-Demographic Factors, Hygiene Practices, and Anaemia Status Among Pregnant Women

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area Description

The study was conducted in Babati district, located in the Manyara region of northern Tanzania. Geographically, Babati is situated at coordinated 04^0 13'S latitude and 035^0 45'E longitude. The district covers a total area of 6069 square kilometers, with 690 square kilometers of arable land. Babati was selected as the study area due to its high prevalence of malnutrition and food insecurity, making it ideal region to explore dietary interventions and their impact to public health. In 2010, Babati district was identified as one of 28 districts in Tanzania facing significant nutritional challenges (Jape, 2017).

Recent assessments (2019-2020) revealed that, over 20% of the district population was experiencing severe food insecurity leading to poor nutritional status among vulnerable groups such as pregnant women and children (Organization, 2023). The high prevalence of anaemia in the district coupled with limited access to iron rich foods provides a compelling justification for conducting research focused on improving iron intake through locally available nutrient dense indigenous vegetables. Babati has a population of 129 572 as per 2022 census with a significant portion of 74 941 between the ages of 15-64, and 49 132 individuals aged 0-14 years. The district has a large proportion of women of reproductive age of 15-49 years making it a critical area for addressing maternal health and nutritional issues (National Bureau statistics, 2022). With gender playing a crucial role in household food distribution and nutrition intake of women in this region is essential for designing effective interventions.

Babati District is located in a semi-arid zone where agriculture is the primary livelihood for most households. Despite the region's agricultural potential, erratic rainfall patterns and prolonged dry spells have negatively impacted food production. Indigenous vegetables, which are well-adapted to local climatic conditions, could offer a sustainable solution to improve nutrition and food security in this context (Liwenga, 2003).

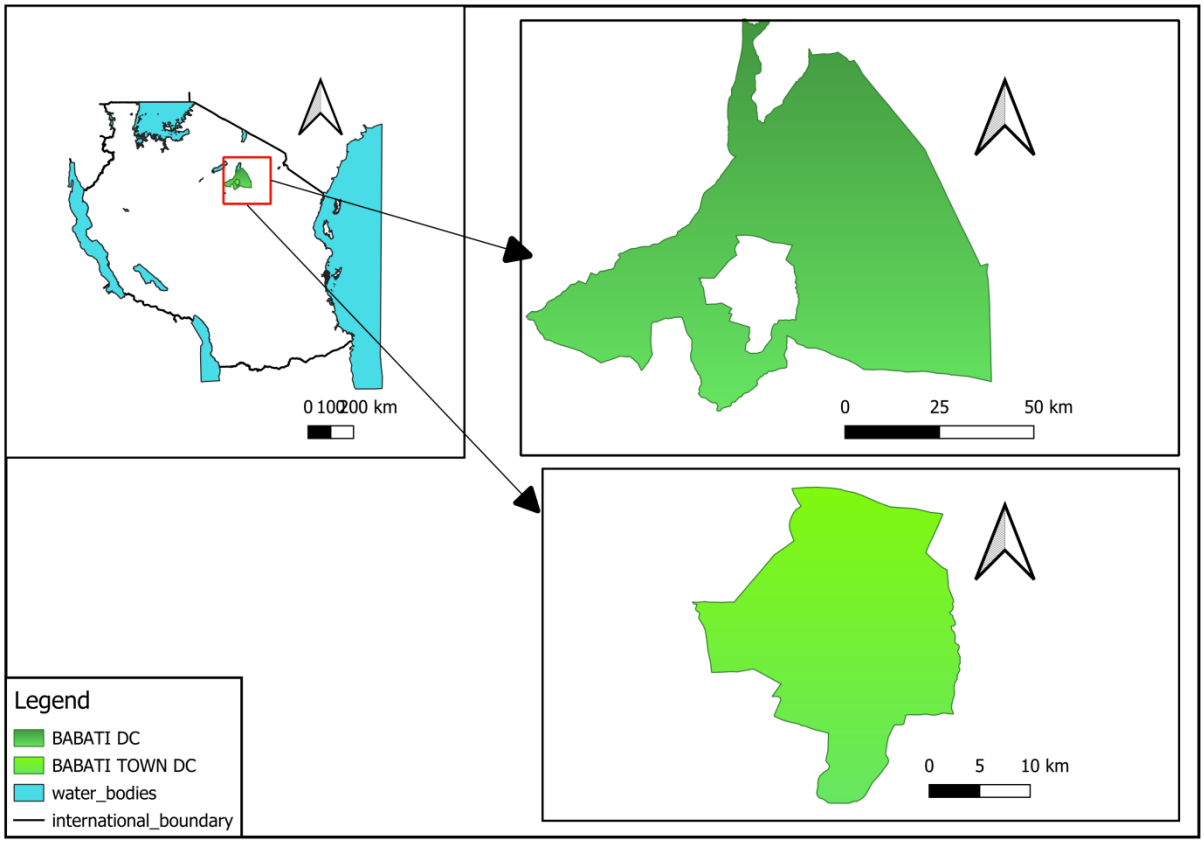

Figure 2: The map of Babati district located in Manyara region where the study was conducted

3.2 Study Design

The study employed a cross-sectional hospital-based survey design. The design was chosen due to suitability in assessing the prevalence of conditions such as pregnancy related anaemia at a single point in time. The design allows the simultaneous collection of data on multiple variables such as dietary intake, hemoglobin levels and demographic factors allowing for the identification of associations relevant to maternal nutrition and health status.

3.3 Study Area and Site Selection

The study was conducted in Babati District, Tanzania at four health facilities namely, Mrara District hospital, Galapo, Bonga and Magugu health Center. These facilities were strategically selected based on their central role in providing antenatal care services to a large population of pregnant women. Their high patient volume and accessibility made them ideal locations for observing maternal health practices and implementing nutritional assessments.

3.4 Study Population

The Target population included pregnant women in their second and third trimesters attending ANC services at the selected facilities during the study period. These trimesters were specifically chosen due to the increased physiological demand for haemoglobin raising risk of developing anaemia. Pregnant women in their first semester and those with pre-existing medical conditions that could influence hemoglobin levels (chronic kidney disease, thalassemia) were excluded to maintain consistency and reduce confounding factors.

3.5 Sample Size Determination

In determining the appropriate sample size for the study, a prevalence rate of 50% was used. The value was selected because no reliable data were available on the consumption of indigenous vegetables among pregnant women in Babati District. The use of 50% as a baseline is a standard practice in social and health research when the true prevalence is unknown as it yields the maximum possible sample size and ensures sufficient statistical power. The sample size was calculated using the standard formula in Equation (1):

$$\textbf{Sample size } (\mathbf{n}) = \frac{\mathbf{z^2pq}}{\mathbf{e^2}} \quad (1)$$

Whereby, n denotes sample size, z is the Z table value at 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 1 p=0.673 as a result sample size used was 340 participants.

Participants were selected using stratified random sampling where the population of pregnant women in Babati was grouped based on health facility attendance. From each selected facility, participants were recruited proportionally using simple random sampling to ensure a representative and unbiased distribution. This method helped to account for potential differences across health centers and allowed for broad generalizability within the study area.

3.6 Participants Inclusion and Exclusion Criteria

The participants for this study were all pregnant women attending ANC in selected health facilities. Only pregnant women in their second and third trimester were recruited as hemoglobin requirements and the risk of anaemia increase significantly during these stages of pregnancy. To ensure the reliability of dietary assessment, only women who had resided in the study area for at least six months were considered eligible to ensure familiarity with local

dietary patterns particularly the use of indigenous vegetables. However, the study excluded women in their first trimester and individuals with diagnosed medical conditions associated with anaemia such as sickle cell anaemia, thalassemia, or chronic illnesses influencing hemoglobin levels. Additionally, any pregnant woman who did not provide informed consent was not included in the study.

3.7 Data Collection Method

The Open Data Kit (ODT) mobile application was used to build and administer a paperless questionnaire comprising of closed and open-ended questions. The questionnaire was used to interview pregnant women attending reproductive health clinics and gather information on socio-demographic characteristics, obstetric history, dietary intake and environmental factors. A structured questionnaire was developed by the researcher based on a review of literatures on anaemia, indigenous vegetable use, and maternal nutrition.

To ensure content validity and clarity, the questionnaire was pretested among 10 pregnant women attending ANC at a non-study health facility in Mbulu district neighboring district with comparable demographic characteristics. This pretest helped refine questions wording, ensuring logical flow, and eliminate ambiguities. The final tool was translated into Swahili to enhance participant comprehension and administered by trained research assistants. Additionally, household visits were conducted with 10 pregnant women from each participating health facility who reported using locally made mixtures to prevent or manage anaemia. These visits involved direct observations of ingredient collection, preparation practices, and documentation of the types of local mixtures consumed.

3.7.1 Assessment of Maternal Dietary Diversity Score

Dietary assessment was conducted using a 24-hour food frequency questionnaire (FFQ), which was adapted to include a list of locally available indigenous vegetables commonly consumed in the study area. While the individual Dietary Diversity Score was used to assess overall dietary quality and nutrient adequacy, the FFQ component was designed to capture the frequency and variety of indigenous vegetable consumption.

3.7.2 Nutrient Intake Assessment using the FFQ

To assess the nutrient intake of pregnant women in Babati district Food Frequency Questionnaire (FFQ) was developed and administered. The FFQ captures information on the

frequency and type of foods consumed over a period and categorized food intakes into frequency groups (Mazengo *et al.,* 1997). The food list used in the FFQ was compiled through a two-stage process. Initially, a core list of food items was adapted from a previously validated FFQ used in rural settings with a dietary pattern similar to those in Babati district. To ensure local relevance, the list was further expanded through qualitative dietary recall interviews with 150 individuals from urban and rural communities within Babati Districts.

The interviews were conducted through home visits by trained local nutritionists who gathered information on commonly consumed foods, traditional dishes, and seasonal items. The final FFQ included 360 food items encompassing simple and composite dishes prepared with multiple ingredients. The nutritional content of each item was calculated using the Tanzania Food Composition Table, which provides standardized macro and micronutrient values per 100 grams of food. For composite dishes, the nutrient content was derived by summing the values of all individual ingredients based on their proportional amounts used in each recipe.

3.8 Laboratory Analysis

Purposive sampling procedure was used to collect sample from the local market. The collected sample were transported in closed polythene bags which were stored in a cool box containing ice maintained at 4℃ to Sokoine University laboratory, then the sample were analyzed in triplicate making 27 total of each parameter.

3.8.1 Indigenous Vegetable Selection

A purposive sampling strategy was employed to select commonly consumed indigenous vegetables from Babati town market. The selected vegetables are shown in Table 2 were identified through local dietary practices and literature review with selection criteria focused on their frequency of consumption and their potential to contribute significantly to iron intake among pregnant women. For each vegetable type, samples were collected from different vendors with about 200 g of edible portions (leaves, fruit, or flower) collected per vendor. After collection, samples were wrapped in perforated polythene bags and stored in a cool box maintained at 4℃ using ice packs. Samples were transported to the Sokoine University Nutrition Laboratory within 4 hours of collection for analysis. Upon arrival, all samples were washed with distilled water, drained and gently blotted. Each composite sample was divided into three subsamples (triplicates).

Table 2: Indigenous Vegetables Analyzed and Their Nutritional Relevance

Common name	Scientific Name	Local name	Part Used	Nutritional Relevance
Amaranth	*Amaranthus spp*	Mchicha	Leaves	Rich in iron, protein and vitamin A
Sweet Potato leaves	*Ipomoea batata*	Majani viazi vitamu	Leaves	Iron, vitamin C and antioxidant
Taro leaves	*Colocasia esculanta*	Kisagaa	Leaves	Iron, calcium and vitamin A
Blackjack	*Bidens pilosa*	Mlenda mwitu	Leaves	High in iron and flavonoids
Baobab	*Adansonia digitata*	Ubuyu	Dried fruit pulp	Rich in vitamin C, enhances iron absorption
Roselle	*Hibiscus sabdariffa*		Calyces (flowers)	Source of iron, vitamin C, and antioxidants

3.8.2 Laboratory Analysis

(i) Iron Analysis

The sample were digested using dry digestion method by taking 1.0 g of homogenized sample incinerated into muffle furnace at 450℃ for four hours. The obtained ashes are then dissolved with 10 ml of 10% hydrochloric acid solution, filtered using No 1 Whatman filter paper and diluted to 25 m with double distilled water. The filtrates are then read in Atomic Absorption spectrophotometer (UNICAM 919 AAS, England) for iron at 248.3 mm (AOAC 1999, Meth no 999, IOA)

(ii) Vitamin C Analysis

Vitamin C is required for two reasons; first the prevention of formation of insoluble and unabsorbable iron compounds and seconds the reduction of ferric to ferrous iron, which seems to be a requirement for uptake of iron into the mucosal cells. The samples were analyzed for Vitamin Content as described by Binesh *et al.* (2005). The vitamin C content of the samples was determined by Spectrophotometry technique using formula from standard plot (Double bean UV-3000 model X-ma 3000 Spectrophotometer Human Co-operation, England).

(iii) Phytate Analysis

Analysis of phytate content was conducted due to fact that presence of phosphate groups makes the phytate highly charged molecules and therefore an excellent chelator, thus is able to form

insoluble complexes with mineral cations such as iron and further decreases their bioavailability when consumed as food. One gram of sample was added to 10 ml 3% TAC (Total Absorbance Chromatograms). Phytates was precipitated as ferric phytate with 0.1% ammonium ferric sulphate. 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 addition of dilute nitric acid, and absorbance of the solution was taken at 519 nm Phytic acid content of the samples was calculated using standard calibration curve (Okiki, 2015).

Preparation and Analysis commonly used indigenous vegetables for Alleviating Anaemia

The selected commonly used indigenous vegetables were prepared following traditional preparation methods commonly used by surveyed participants. Fresh leafy ingredients, including sweet potato leaves, amaranth, blackjack and African nightshade were washed with clean water to remove dirt, debris and contaminants. The washing process was repeated twice to ensure cleanliness. For mixtures such as sweet potato leaves with amaranth and lemon juice, the leaves were chopped into small pieces and lightly steamed for approximately 5 minutes to preserve their nutrient content while improving digestibility.

After streaming, fresh lemon juice was squeezed and mixed with the cooked leaves before consumption. For blackjack and baobab powder, the blackjack leaves were pounded into a paste using a mortar and pestle or boiled in water for about 10 minutes before mixing with baobab powder. The roselle petals were soaked overnight with baobab in clean water at room temperature for 12 hours to enhance the extraction of bioactive compounds.

Other combinations such as amaranth with Africa nightshade, bitter lettuce with amaranth and African spider flower with amaranth were prepared by chopping leaves into smaller pieces and boiling them in water for 3 to 7 minutes. The boiling time was monitored to maximize nutrient retention while reducing bitterness and improving palatability. The mixtures were cooled to room temperature before undergoing laboratory analysis to determine vitamin C and phytate content.

3.9 Statistical Analyses

Statistical analyses were conducted using R software (version 4.2.2) with the Rcmdr. Plugin. NMBU. Descriptive statistics were used to summarize demographic data, prevalence of anaemia, and usage patterns of indigenous vegetables and local decoctions. Frequencies and

percentages were reported for categorical variables, while means and standard deviations (or medians and interquartile ranges, depending on data distribution) were used for continuous variables, including laboratory-determined nutrient values.

To assess the nutrient content of indigenous vegetable preparations, vitamin C and phytate concentrations measured a continuous variables were analyzed using inferential statistical test. One way ANOVA was used to compare nutrient levels across different preparation methods (boiling, steaming, sun-drying), followed by Tukey's post hoc test to identify specific group differences. Where assumptions for parametric tests were not met, Kruskal-Wallis and Dunn's post hoc tests were applied.

These tests allowed for a multiple comparison of nutrient retention across various preparation techniques. Where paired T-tests were also employed to assess nutrient differences within the same vegetable under different processing conditions. All nutrient data were tested for normality using the Shapiro-Wilk test prior to analysis, and non-normal variables were log-transformed or analyzed with non-parametric alternatives.

To investigate potential associations between nutrient intake (laboratory-derived values) and anaemia status, Chi-square tests were used for categorical variable comparisons. However, for continuous predictors such as vitamin C and phytate levels, logistic regression models were developed to examine the association between nutrient concentration and binary anaemia outcomes (anemic vs. non-anemic), adjusting for possible confounders such as age, gestational age, dietary diversity score, and socioeconomic status. Odds ratios with 95% confidence intervals were reported.

3.10 Ethical Approval and Consent Processes

Ethical approval for the study was obtained from the National Institute for Medical Research (NIMR), with reference number NIMR/HQ/R.8a/Vol.IX/4306. Prior to data collection, all participants were provided with information about the purpose, procedures, potential risks and benefits of the study. Written informed consent was obtained from each participant with assurance of voluntary participation and they could withdraw at any time without penalty. The privacy on participants was maintained by conducting interviews in secure and private settings. Confidentiality was maintained by anonymizing all data during transcription and analysis with no disclosed reports or publications. All data were securely stored and accessed only by authorized personnel.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

The relationship between social demographic factors and anaemia prevalence was also examined, revealing key insights into risk factors such as age, marital status and nutritional knowledge. Additionally, the present study evaluates dietary practices and food using Dietary Diversity Score (DDS) to measure nutritional adequacy. Finally, local decoctions and mixtures were investigated used for anaemia prevention, analyzing their vitamin C and phytate content. Overall aim was to enhance understanding on the factors affecting iron availability and nutritional status among pregnant women in Babati district contributing to strategies for reducing anaemia and improving maternal health outcomes.

4.2 Demographic and Socioeconomic Characteristics of the Study Population

A total of 340 participants were included in the study from four health facility locations. Mrara accounted for the highest proportion of respondents (43%), followed by Bonga (20%), Magugu (19%) and Galapo (18%). The mean number of participants in Galapo was 68. The age distribution of the study participants was in a range from 19 to 49 years. The majority of the participants fell within 19-35 years category (80.88%). Regarding marital status, the majority of participants were married (74.41%, n = 253) while 25.58% (n = 87) reporting cohabitating. Household size varied among respondents, with approximately 19.11% (n = 65) lived in households with 1-2 members, 46.76% (n = 165) lived in households with 3-5 members and 34.11% (n = 110) reported having more than five members in their household.

In terms of maternal education more than half of the mothers (57.35%, n = 195) had attained primary education. A further 28.52% (n = 97) had completed secondary education, 8.52% (n = 29) had achieved higher education while 5.58% (n = 19) were illiterate. Regarding maternal occupation, the majority were farmers (41.76%, n = 142), followed by housewives followed by housewives (33.23%, n = 113), those engaged in business (17.05%, n = 58), and those in formal employment (7.94%, n = 27).

For paternal occupation, half of the fathers were farmers (50.58%, n = 172), while 27.05% (n = 92) were in business and 22.35% (n = 76) were formally employed. Household monthly income also varied across participants. Almost half (49.41%, n = 168) reported an income

between 101 000 and 400 000 Tanzanian Shillings (TZS). Meanwhile, 34.11% (n = 116) reported earnings above 400 000 TZS, and 16.47% (n = 56) earned between 20 000 and 100 000 TZS. These figures provide a comprehensive view of the socio-demographic characteristics of the study population (Table 3).

The characteristics observed in the study provide critical insights into the background and living conditions across selected health facilities. The distribution of responds across four health facility catchment areas revealed that Mrara contributed highest number of participants followed by Bonga, Magugu and Galapo. The uneven distribution reflects population density, service availability and accessibility where distance and infrastructure may influence health seeking behaviour.

The distribution of respondents across four health facility catchment areas revealed that Mrara contributed the highest number of participants (43%), followed by Bonga (20%), Magugu (19%), and Galapo (18%). The uneven distribution may reflect population density, service availability, or accessibility issues, particularly in rural settings where distance and infrastructure may influence health-seeking behavior.

With regard to marital status, the majority of participants were married (74.41%), while 25.58% reported cohabitating. These findings align with previous literature suggesting that marital status plays a significant role in health behavior and access to resources (Adamu *et al*., 2017; Organization, 2004; Teshale *et al.,* 2020). Married individuals often have greater emotional and logistical support, which can facilitate participation in health programs and improve health outcomes.

In contrast, those who are unmarried or in informal unions may have fewer social supports, which has been linked to reduced healthcare access in other studies (Baart *et al.,* 2011). Household size is an important determinant of nutritional status and access to health services, particularly in low-resource settings. Larger households often face increased demand for food, healthcare and other basic needs, which can strain limited resources and contribute to food insecurity. This can be especially challenging for pregnant women, whose dietary needs are elevated and who may be deprioritized in food allocation in some cultural contexts.

On the other hand, smaller households may benefit from reduced financial pressure and simplified food distribution. However, they may lack the broader support systems such as shared caregiving, household labor and income diversification that are more common in

extended or multigenerational living arrangements. In the context of anaemia prevention, understanding household size dynamics is critical for tailoring interventions that promote equitable access to nutritious, iron-rich foods like indigenous vegetables.

Low maternal education is often associated with reduced health literacy, limited understanding of nutrition and child care practices, and lower utilization of healthcare services (Ickes *et al.,* 2015; Johri *et al*., 2016). Previous studies have also shown that educational attainment is positively associated with participation in health programs and research (Frost, 2005) . The occupational status of mothers revealed a strong dependence on informal employment, particularly subsistence farming and domestic roles such as housewifery. A smaller proportion of mothers were engaged in small-scale business or formal employment. This pattern reflects the rural and agrarian nature of the study setting, where opportunities for formal employment are often scarce.

Farming remains a critical livelihood strategy, yet it is highly susceptible to seasonal and environmental variability, which can impact household income stability and food availability. Fathers exhibited a similar occupational distribution, with the majority involved in agriculture, followed by business activities and formal employment. These occupational patterns align with national trends in rural Tanzania, where agriculture is the predominant economic activity.

In the context of maternal nutrition and anaemia prevention, occupational roles play a crucial role in determining time availability, decision-making power and access to nutritious foods including the cultivation and consumption of indigenous vegetables. Income results further support the characterization of the study population as predominantly low to middle income. As documented in earlier research, lower household income is closely linked to reduce healthcare utilization, limited dietary diversity and heightened vulnerability to economic shocks.

Income level significantly influences a household's ability to access and afford healthcare services, including transportation, medications and nutritious foods (Dammann & Smith, 2009; Kushel *et al.,* 2006). In the context of anaemia prevention among pregnant women, economic constraints can limit the availability and intake of iron-rich foods, even when culturally appropriate options such as indigenous vegetables are locally available. The observed income patterns may partly explain variations in health outcomes and the degree of engagement with maternal health services across the population.

Table 3: Demographic characteristics of the study population

Characteristics	N	%	Mean
Health facility Location			
Bonga	68	20	
Galapo	60	18	68
Magugu	67	19	
Mrara	145	43	
Marital Status			
Married	253	74.41	170
Cohabitating	87	25.58	
Household members			
1-2	65	19.11	
3-5	165	46.76	
Above 5	110	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 (TZS)			
20 000-100 000	56	16.47	
101 000-400 000	168	49.41	
Above 400 000	116	34.11	
Age Group (Years)			
19-35	275	80.88	
36-49	65	19.12	

4.3 Knowledge, Attitudes and Practices regarding to Hygiene, 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 anaemia. The section explores the knowledge, attitudes, and behaviors of pregnant women in Babati District, shedding light on how these factors contribute to anaemia prevention and overall pregnancy outcomes. In Table 4, all participants 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 anaemia (χ^2= 9.352, df = 1, p = 0.0022), highlighting the importance of this practice in preventing anaemia. Conversely, a lack of hand washing after using the toilet was associated with an elevated risk for anaemia.

The present results support the hypothesis that, various socio-demographic factors, particularly poor wealth and WaSH indicators such as sharing toilet facilities are significantly associated with prevalence of anaemia. The presence of shared facilities can exacerbate the risk of infectious disease outbreaks which in turn contributes to both conditions. Furthermore, addressing anaemia requires a multipurpose approach that considers not only dietary factors but the cyclical relationship between infectious disease, inflammation, and nutritional status. For instance, infections from helminthes and other parasites have been strongly linked to anaemia and other parasites among school children (Aemiro, 2022; Lambrecht *et al*., 2022).

Additionally, inflammation is recognized as a critical factor contributing to anaemia in school going girls (Gupta *et al*., 2022). The study found a significant association between handwashing practices and reduced anaemia risk. The study results also revealed that access to private sanitation; treated water and overall wealth acting as a proxy for household conditions were all associated with anaemia. Recent studies have shown that improved access to sanitation reduces anaemia risk among women of childbearing age in southern Africa (McLaren, 2022), and access to clean water is linked to better nutritional outcomes in preschool children in Ethiopia (Wasihun *et al*., 2020).

Moreover, The findings regarding the positive relationship between using shared toilets and anaemia among adolescents' girls further emphasize the interconnectedness of hygiene and nutritional health. In terms of mosquito net ownership, 86% of pregnant women possessed mosquito nets, and an impressive 84% actively used them. Malaria is a known contributor to anaemia during pregnancy, so this high level of prevention is likely helping to mitigate one risk factor for anaemia in this population.

The interplay between malaria and anaemia is significant particularly in regions where malaria is endemic. Anaemia is often exacerbated by malaria infections which lead to the destruction of red blood cells and impaired production of new blood cells (Wasihun *et al*., 2020). This relationship is further complicated by the presence of other infectious diseases and nutritional deficiency which frequently occur in affected populations.

In areas with moderate to high malaria transmission such as Malawi severe anaemia is linked to bacterial infections, HIV, and nutritional deficiencies like vitamin A and B12 (Calis *et al.,* 2008). These conditions not only contribute to the development of anaemia but also complicate its management and treatment. Moreover, malaria has been known to influence the prevalence of certain genetic disorders. For example, conditions such as sickle cell anaemia and glucose-6-phosphate dehydrogenase deficiency are common in regions where malaria is prevalent.

While these genetic traits can provide some protection against the severe effects of malaria, they can also contribute to anaemia. Sickle cell disease, prevalent in sub-Saharan Africa, is often aggravated by malaria, leading to severe anaemia episodes (Williams, 2016). Similarly, individuals with G6PD deficiency face a heightened risk of developing severe anaemia as a complication of malaria (Uyoga *et al*., 2015). The relationship between malaria and anaemia is characterized by a cycle of interdependence where malaria exacerbates anaemia, while genetic and environment factors complicate both conditions. This is supported by our findings, which indicate that malaria transmission is associated with increased rates of anaemia.

High malaria cases are often correlated with inadequate use of mosquito nets, which are a critical tool for malaria prevention. The present findings indicate that communities with lower rates of mosquito net ownership and usage experience significantly higher incidences of malaria. This suggests that insufficient adherence to mosquito net utilization directly contributes to the transmission of malaria in these populations.

In the awareness of iron and folic acid supplementation on the pregnant women, 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 anaemia.

Despite awareness of iron and folic acid supplements, only 24.7% (N=72) of the respondents indicated a proper understanding of their reasons for use, such as anaemia prevention and fetal development. The remaining 75.3% (N=268) lacked sufficient understanding, which could impact adherence to supplementation. The association between understanding the reasons for supplementation and reduced anaemia risk was statistically significant, with a p-value of 0.001. 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 anaemia and related complications.

The fact that only a quarter of the women fully understood the reasons for using iron and folic acid supplements suggests a knowledge gap that could be addressed through targeted educational interventions. This gap in understanding likely contributes to the lower adherence rates among some women, as those who do not comprehend the benefits of supplementation may be less likely to use them consistently. Despite this knowledge gap, adherence to iron and folic acid supplementation was relatively high at 75.3% ($p = 0.025$). 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 4: Knowledge, attitude and practices regarding to Hygiene, Nutrition, and Supplement Use in Pregnancy

Variable	N (%)		P-values
	YES	NO (0)	
Toilet usage	340	(100)	
Hand washing facility	10 (31.5)	233(68.5)	$p = 0.0022$
Mosquito net usage	286 (84.1)	54(15.8)	
Knowledge about folic acid and iron supplementations	215 (63.2)	125 (36.8)	$p = 0.032$
Reasons for using iron and Folic acid supplements	72 (24.7)	268(75.3)	$p = 0.001$
Adherence using iron and folic acid supplements	256 (24.7)	84(75.3)	$p = 0.025$

4.4 Pregnancy Information and Nutritional Status

To explore the nutritional benefits of locally grown indigenous vegetables that optimize iron content and prevent pregnancy related anaemia, the nutritional status of pregnant women was surveyed and results are shown in Table 5. The nutritional status is crucial to understand the impact of dietary interventions of the pregnancy related deaths. Among the surveyed pregnant women, 46.5% were in their third or fourth pregnancy and 20.58% had experienced five or more pregnancies.

Despite the increased nutritional demands associated with multiple pregnancies, the vast majority (92.06%) of women maintained a normal nutritional status. This suggests that, while their diets may include a variety of food sources, it is not possible to definitively attribute their nutritional status solely to indigenous vegetables. Other factors, such as the consumption of iron-rich foods from different sources or supplementation provided through attending the Reproductive and Child Health (RCH) prenatal care centers, may also contribute significantly

to their overall nutritional intake and 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 levels and preventing anaemia. This is further supported by the parity data, where 81% of women report having three to four children. Such multiple pregnancies increase the physiological demands on the body, particularly the need for iron and other essential nutrients to support maternal and fetal health. Higher parity often leads to increased nutritional requirements, which makes access to timely antenatal care crucial.

Despite the heightened nutritional needs associated with multiple pregnancies, only 27.05% of women sought antenatal care before 12 weeks, while 53.52% visited between 12 and 20 weeks, and 19.41% delayed their care until after 20 weeks. Early antenatal care is critical for identifying potential health risks, including anaemia, 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 multiple pregnancies and varying antenatal care attendance, 92.06% of women maintained a normal nutritional status based on MUAC measurements. This suggests that many women are meeting their nutritional needs through diverse dietary sources, including a mix of locally available foods. While some consumed nutrient-dense foods such as dark green vegetables (39.69%) and legumes (43.35%), others may have met their iron requirements through alternative sources such as animal products (e.g., meat/fish at 48.52%) or iron supplementation from antenatal care visits. These findings underscore the importance of promoting early antenatal care and continued dietary support to further optimize iron intake and prevent pregnancy-related anaemia in this population.

Table 5: Pregnancy information and nutrition status

Variable	Frequency	Percentage (%)
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

4.5 Social Demographic Factors Related to Anaemia 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 range, the body cannot deliver adequate oxygen to vital organs leading to anaemia. Hemoglobin data collected from participants' clinic cards revealed that 45% of pregnant mothers were anemic while 55% were not (Table 6).

It is important to note that physiological hemoglobin needs are higher at higher altitudes due to the lower oxygen concentration in the atmosphere. Additionally, smoking can increase hemoglobin concentrations. To accurately assess the prevalence and impact of anaemia in high-altitude populations, hemoglobin levels should be adjusted downward for individuals living at altitudes above 1000 meters to avoid underestimating anaemia prevalence. However, the data from this study were not adjusted for altitude. This study found a significant correlation between age and the likelihood of being anemic (χ^2=6.43, df = 2, p=0.04), with older mothers, particularly those aged 36 to 49, exhibiting a lower risk of anaemia.

Young pregnant women were more prone to anaemia, which may be attributed to several factors. Inadequate nutrition is a key factor, as younger women may lack access to the proper nutrients, such as iron and folate, essential for healthy blood production. Additionally, adolescents and younger women are still undergoing physical growth, which increases the body's demand for iron and other nutrients.

Their rapid growth, combined with demands of pregnancy, can result in insufficient iron stores, further contributing to anaemia. 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 importance of iron and folic acid intake during this critical period. These factors likely contribute to their reduced risk of anaemia compared to their younger counterparts.

Marital status also showed a significant association with anaemia (χ^2=4.1, df=1, p=0.04). Being married was associated with a lower likelihood of anaemia, 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 anaemia compared to their single, divorced, widowed, or separated counterparts (Olusola *et al*., 2023). The association between marital status and anaemia 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. Additionally, the stability that comes with marriage may reduce stress levels and promote healthier living conditions, contributing to lower rates of anaemia. The findings on socioeconomic factors align with those of previous studies, for instance, higher prevalence of anaemia and iron deficiency among Korean adolescence girls correlated positively to those with inferior socioeconomic factors such as household income (Kim *et al*., 2014). One plausible explanation for the lower rates of anaemia among those with higher household incomes is their greater ability to afford iron-rich foods, such as red meat, which plays a crucial role in preventing anaemia and maintaining healthy iron levels (Gompakis *et al*., 2007).

Table 6: Association of Socio-Demographic Factors with Anaemia in Pregnancy

Characteristics	Anemic (n=186)	Non-Anemic (n=154)	Chi-Square	df	P-Value
Age			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 (years)			5.8	2	0.02
≤ Primary	147 (78%)	105 (68.2%)			
≥ Secondary	41 (22%)	49 (31.8%)			

4.6 Dietary Practices and Food Security among Pregnant Women in Babati District

To assess the types of indigenous vegetables commonly used by pregnant women to prevent and manage anaemia participants were asked about their frequency of consumption of locally available indigenous vegetables using FFQ. The responses were categorized as Daily, Weekly, Monthly and Occasional/Seasonal. Table 7 presents the reported frequency of consumption for each vegetable. The most frequently consumed vegetables on a daily basis were amaranth leaves (48.5%), sweet potato leaves (42.4%).

Table 7: Frequency of consumption of indegeneous vegetables among pregnant women in Babati region (N = 340)

Indigeneous	Daily	Weekly	Monthly	Occassional	Never
Amaranth leaves	165 (48.5%)	103 (30.3%)	38 (11.2%)	21 (6.2%)	13 (3.8%)
Sweet potato leaves	144 (42.4%)	112 (32.9%)	51 (15.0%)	18 (5.3%)	15 (4.4%)
African nightshade	128 (37.6%)	114 (33.5%)	49 (14.4%)	29 (8.5%)	20 (5.9%)
Pumpkin leaves	92 (27.1%)	132 (38.8%)	63 (18.5%)	38 (11.2%)	15 (4.4%)
Cowpea leaves	86 (25.3%)	120 (35.3%)	74 (21.8%)	45 (13.2%)	15 (4.4%)
Spider plant	78 (22.9%)	95 (27.9%)	67 (19.7%)	56 (16.5%)	44 (12.9%)
Hibiscus leaves	61 (17.9%)	88 (25.9%)	92 (27.1%)	59 (17.4%)	40 (11.7%)
Chinese cabbage	55 (16.2%)	82 (24.1%)	98 (28.8%)	71 (20.9%)	34 (10.0%)
Wild mustard	42 (12.4%)	76 (22.4%)	89 (26.2%)	75 (22.1%)	58 (17.1%)
Cassava leaves	33 (9.7%)	62 (18.2%)	97 (28.5%)	88 (25.9%)	60 (17.6%)

4.7 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 DDS was calculated based on 9 food groups as shown in Table 8. The pregnant woman got 1 point if she consumed something at least 10 g from a unique food group in 24 hours dietary record. The following set of 9 food groups starchy/staples, Dark green vegetables, Vitamin A, fruits/vegetables, other fruits/vegetables, organic 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 required dietary diversity which is having more than 5 food groups.

The relationship between dietary diversity and health outcomes, including improved immune function, is well established. A diverse diet plays a crucial role in maintaining the immune system, which serves as the body first line 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 in supporting its function (Richards & Rickard, 2020). Among these, diet is particularly important, as it provides the necessary nutrients to build and maintain immune defenses.

The antioxidants obtained from the diet are referred to as exogenous antioxidants, while those produced naturally by the body are known as endogenous antioxidants. The inclusion of these antioxidant-rich foods in the diet helps to strengthen the body's defenses against disease, as demonstrated by various studies. For example, turmeric has been shown to possess significant anti-inflammatory properties (Singletary, 2010) and citrus fruits are a well-known source of vitamin C, which enhances immune function (Klimek *et al.,* 2020). These findings support the broader notion that a diversified diet is beneficial not only for immune health but also for other outcomes such as improved hemoglobin levels, birth weight, and child development during pregnancy.

Table 8: 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
Organ meat	43	12.64
Meat/fish	165	48.52
Eggs	158	48.52
Legumes	148	43.35
Milk and milk products	75	11.98

Data from this research **N=340**

4.8 Local Decoctions/Mixtures used for Prevention and Management of Anaemia During Pregnancy

Table 9 provides an insightful overview of the frequently used mixtures among the surveyed participants for the alleviation of anaemia 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 combined with baobab powder, reported by 59 (17.4%), indicating a preference for this combination among the surveyed population. Moreover, the utilization of rosella 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 with a composition at 17(5%), 5 (1.5%), and 3 (0.9%) respectively. Based on the mentioned combinations, the most used were selected and analyzed for their vitamin C, iron (mineral), and phytate content.

Table 9: 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
None	85	25

4.9 The Proximate Results

Table 10 presents the mean composition of various components includes Vitamin C, iron, and

Phytate content expressed in mg. Each sample is derived from different materials and preparation methods commonly used by pregnant women in the study area. A combination of boiled amaranth, sweet potato leaves, and lemon has high Vitamin C contents at 43.2±0.26 mg/g, 0.034±0.077 mg/g of iron, and 0.71±0.04 mg/g. raw sweet potato leaves provide a moderate amount of vitamin C but a higher Iron content (0.5 mg/g) and significant Phytate content (42 mg/g). The blackjack and baobab mixture has the highest vitamin content among the samples with 45 mg/g, 0.17 mg/g of phytate, and 0.00 mg/g of iron. This combination is excellent for Vitamin C intake but not a source of Iron. The leaves were boiled and then separated from the juice, as pregnant women reported using the juice rather than the leaves.

The black juice contained 2.1 mg/g of vitamin C and no detectable Iron, with a Phytate content of 1.12 mg/g. This suggests the juice has limited nutritional value in these aspects compared to the raw or whole plant. The roselle and baobab mixture shows a moderate Vitamin C content (32.82 mg/g) and Phytate content (1.21 mg/g) but no significant Iron content. It is good for Vitamin C supplementation. The process of soaking roselle overnight results in moderate Vitamin C content (18.4 mg/g) and higher Iron content (1.4 mg/g) along with moderate Phytate levels (5.9 mg/g). Soaking might have enhanced Iron availability, but some Vitamin C is lost. Baobab powder contains 8.04 mg/g of Iron and 24 mg/g of Vitamin C along with a high Phytate level of 35 mg/g. Blackjack in its raw form provides 63 mg/g of Vitamin C and 15 mg/g of Iron, with a minimal Phytate content of 0.0025 mg/g. Raw amaranth leaves offer 44.5 mg/g of Vitamin C and 2.3 mg/g of Iron, but have a Phytate level of 42 mg/g.

The proximate composition reveals notable variability in the nutritional profiles of indigenous vegetables and their combinations commonly consumed by pregnant women in Babati District. The most significant findings relate to the levels of vitamin C, iron and phytate with direct implications for anaemia prevention and management. The highest vitamin C content was observed in raw blackjacks leaves and the blackjack and baobab mixtures followed closely by raw amaranth. These sequences align with findings from Odhav *et al*. (2007), reporting *Bidens pilosa* (blackjack) and *Amaranthus spp.* as the richest sources of vitamin C among African leafy vegetables. Vitamin C plays a crucial role in enhancing non-heme iron absorption which is beneficial for pregnant women consuming plant based diets (Richards & Rickard, 2020).

For iron contents, raw blackjack and baobab demonstrated the highest levels followed by raw amaranth and soaked roselle. These levels surpassed those reported by Fasuyi (2006) for amaranthus and other traditional greens. Notably, food soaking overnight improved iron

content compared to the raw mixtures that was likely contributed to phytate reduction which is a known inhibitor for iron absorption (Hurrell *et al*., 2003). Phytate levels varied significantly with highest found in raw sweet potato leaves and raw amaranth and baobab powder. Phytate are known to hinder iron and zinc absorption due to their chelating effects (Shokunbi & Okeowo, 2011).

Conversely, blackjack raw and the boiled amaranth sweet potato and lemon mixture exhibited the lowest phytate concentration supporting improved mineral bioavailability. This is consistent with findings by Mbithi-Mwikya *et al*. (2000), who noted that thermal processing, such as boiling, reduces phytates and other antinutritional compounds.

Table 10: ***Mean composition of the sample is presented in mg/g***

S/N	Sample	Vitamin C	Iron (Fe)	Phytate
1.	Boiled amaranth sweet potato leaves lemon	43.2±0.26	0.034±0.077	0.71±0.04
2.	Sweet potato leaves raw	21.8±1.85	0.5±0.22	42.0±0.06
3.	Blackjack+ baobab	45±2.29	0.00±0.12	0.17±0.07
4.	Blackjack juice	2.1±0.03	0.00±0.00	1.12±0.00
5.	Roselle +baobab	32.82±1.21	0.00±0.64	1.21±0.00
6.	Roselle soaked overnight	18.4±0.39	1.4±2.28	5.9±2.27
7.	Baobab powder	24±1.19	8.04±0.11	35±0.00
8.	Black jack raw	63±1.19	15±0.20	0.0025±0.01
9	Amaranth raw	44.5±0.67	2.3± 0.01	42.0±0.02

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study systematically examined the prevalence and contributing factors of anaemia among pregnant women in Babati District, with a focus on the role of dietary intake from iron-rich indigenous vegetables. The findings highlight that iron deficiency anaemia is a significant health issue, particularly among pregnant women, with serious implications for maternal and child health The results of our study support the hypothesis that poor wealth and hygiene indicators, such as sharing toilet facilities, are significantly associated with the prevalence of anaemia. Shared sanitation facilities exacerbate the risk of infectious diseases, which contribute to both anaemia and stunting. This emphasizes the need for a multipronged approach to addressing anaemia that includes dietary factors and considers the cyclical relationship between infectious diseases, inflammation, and nutritional status.

The study highlights the importance of addressing infectious diseases as part of the fight against anaemia. Additionally, we identified a significant association between handwashing practices and reduced anaemia risk. Access to private sanitation and treated water was linked to lower rates of anaemia, emphasizing that inadequate hygiene practices can increase the likelihood of infections, which can further exacerbate anaemia in this vulnerable population. The findings also indicated that malaria prevention efforts, such as the ownership and use of mosquito nets among pregnant women (86% and 84%, respectively), likely mitigate one of the significant risk factors for anaemia in this population

The interplay between malaria and anaemia is critical, particularly in regions where malaria is endemic. Anaemia is exacerbated by malaria infections that lead to the destruction of red blood cells and impaired erythropoiesis. Additionally, our investigation revealed that socioeconomic factors significantly impact the prevalence of anaemia The study found that married women exhibited lower odds of anaemia compared to their unmarried counterparts. This relationship underscores the influence of socioeconomic conditions on health outcomes. Married women may benefit from increased emotional and financial support, enhancing their access to nutritious food and healthcare during pregnancy.

Furthermore, the exploration of dietary diversity revealed that the consumption of indigenous vegetables can enhance iron intake, providing a potential strategy for alleviating anaemia.

The findings suggest that to empower maternal health in the Babati District, interventions should be holistic, considering both nutritional aspects and social and economic factors. Tailored approaches accounting for the complex interplay between age, marital status, and anaemia are essential for effectively combating anaemia in vulnerable population

5.2 Recommendations

The findings of this study indicate significant associations between various factors and the prevalence of anaemia among pregnant women and adolescents in Babati District. Despite the insights gained, further research is warranted, and the following recommendations are proposed:

(i) Promote the use of nutrient-rich indigenous vegetables such as amaranth, sweet potato leaves, and blackjack as sustainable and culturally acceptable dietary strategies for improving iron intake among pregnant women.

(ii) Incorporate education on food preparation methods into maternal health programs to enhance nutrient retention and reduce antinutrient effects (e.g., high phytate content), which can inhibit iron absorption.

(iii) Strengthen nutrition education at antenatal care clinics to improve pregnant women's knowledge of iron-rich foods and the importance of dietary diversity in preventing anaemia.

(iv) Encourage community-level interventions that promote the cultivation and regular consumption of indigenous vegetables, especially in food-insecure rural areas like Babati.

(v) Further research is recommended to explore bioavailability of iron in commonly used traditional mixtures and to evaluate the clinical impact of promoting indigenous vegetables as part of anaemia reduction strategies.

REFERENCES

Adamu, A. L., Crampin, A., Kayuni, N., Amberbir, A., Koole, O., Phiri, A., Nyirenda, M., & Fine, P. (2017). Prevalence and risk factors for anaemia severity and type in Malawian men and women: Urban and rural differences. *Population Health Metrics*, 15(1), Article 12.

Adjei-Banuah, N. Y., Aduah, V. A., Ziblim, S. D., Ayanore, M. A., Amalba, A., & Mogre, V. (2021). Nutrition knowledge is associated with the consumption of iron-rich foods: A survey among pregnant women from a rural district in Northern Ghana. *Nutrition and Metabolic Insights, 14*, 1–8.

Aemiro, A., Menkir, S., Tegen, D., & Tola, G. (2022). Prevalence of soil-transmitted helminthes and associated risk factors among people of Ethiopia: A systematic review and meta-analysis. *Infectious Diseases: Research and Treatment, 15*, 1–12.

Azhar, B. S., Islam, S., & Karim, R. (2021). Prevalence of anaemia and associated risk factors among pregnant women attending antenatal care in Bangladesh: A cross-sectional study. *Primary Health Care Research & Development*, *22*, e61.

Baart, A. M., De Kort, W. L., Moons, K. G., & Vergouwe, Y. (2011). Prediction of low haemoglobin levels in whole blood donors. *Vox Sanguinis, 100*(2), 204–211. https://doi.org/10.1111/j.1423-0410.2010.01391.x

Banerjee, A., Athalye, S., Shingade, P., Khargekar, V., Mahajan, N., Madkaikar, M., & Khargekar, N. (2024). Efficacy of daily versus intermittent oral iron supplementation for prevention of anaemia among pregnant women: A systematic review and meta-analysis. *EClinicalMedicine, 74*, 103844. https://doi.org/10.1016/j.eclinm.2024.103844

Benson, A. E., Shatzel, J. J., Ryan, K. S., Hedges, M. A., Martens, K., Aslan, J. E., & Lo, J. O. (2022). The incidence, complications, and treatment of iron deficiency in pregnancy. *European Journal of Haematology, 109*(6), 633–642. https://doi.org/10.1111/ejh.13884

Bergman, M., Varshavsky, L., Gottlieb, H. E., & Grossman, S. (2001). The antioxidant activity of aqueous spinach extract: Chemical identification of active fractions. *Phytochemistry, 58*(1), 143–152. https://doi.org/10.1016/S0031-9422(01)00217-6

Bhatnagar, R. S., & Padilla-Zakour, O. I. (2021). *Plant-Based Dietary Practices and Socioeconomic Factors.* https://scholar.google.com

Brannon, P. M., & Taylor, C. L. (2017). Iron supplementation during pregnancy and infancy: Uncertainties and implications for research and policy. *Nutrients, 9*(12), 1327. https://doi.org/10.3390/nu9121327

Buzigi, E., Pillay, K., & Siwela, M. (2020). Caregiver perceptions and acceptability of a provitamin A carotenoid, iron and zinc rich complementary food blend prepared from common bean and pumpkin in rural Uganda. *Nutrients, 12*(4), 906.

Calis, J. C., Phiri, K. S., & Van Hensbroek, M. B. (2008). Severe anaemia in Malawian children: Reply. *New England Journal of Medicine, 358*(21), 2291.

Caplan, M. (2007). Scientific review: The role of nutrients in immune function of infants and young children: Emerging evidence for long-chain polyunsaturated fatty acids. *Nestlé Nutrition Workshop Series*, *62*, 183–196.

Chaparro, C. M., Suchdev, P. S., & Nutrition, I. (2019). Anaemia epidemiology and determinants. *Annals of the New York Academy of Sciences, 1450*, 15–31.

Costanza, J., Camanni, M., Ferrari, M. M., De Cosmi, V., Tabano, S., Fontana, L., Radaelli, T., Privitera, G., Alberico, D., Colapietro, P., Motta, S., Sirchia, S., Stampalija, T., Tabasso, C., Roggero, P., Parazzini, F., Mosca, F., Ferrazzi, E., Bosari, S.,…& Agostoni, C. (2022). Assessment of pregnancy dietary intake and association with maternal and neonatal outcomes. *Pediatric Research,* 91(7), 1890–1896.

Dammann, K. W., & Smith, C. (2009). Factors affecting low-income women's food choices and the perceived impact of dietary intake and socioeconomic status on their health and weight. *Journal of Nutrition Education and Behavior, 41*(4), 242–253.

Derso, T., Abera, Z., & Tariku, A. (2017). Magnitude and associated factors of anaemia among pregnant women in Dera District: A cross-sectional study in northwest. *BMC Research Notes, 10*(1), 1–8.

Dinh, J., Angeloni, J. T., Pederson, D. B., Wang, X., Cao, M., & Dong, Y. (2014). Cranberry extract standardized for proanthocyanidins promotes the immune response of

Caenorhabditis elegans to *Vibrio cholerae* through the p38 MAPK pathway and HSF-1. *Plos One, 9*(7), e103290. https://doi.org/10.1371/journal.pone.0103290

Duarte, P. F., Chaves, M. A., Borges, C. D., & Mendonça, C. R. B. (2016). Avocado: Characteristics, health benefits and uses. *Ciência Rural, 46*(4), 747–754.

Fasuyi, A. (2006). Nutritional potentials of some tropical vegetable leaf meals: Chemical characterization and functional properties. *African Journal of Biotechnology, 5*(1), 49–53.

Fisher, A. L., & Nemeth, E. (2017). Iron homeostasis during pregnancy. *The American Journal of Clinical Nutrition, 106*(Suppl_6), 1567S–1574S.

Frost, M. B., Forste, R., & Haas, D. W. (2005). Maternal education and child nutritional status in Bolivia: Finding the links. *Social Science & Medicine, 60*(2), 395–407.

Gebrie, M., Id, W., Alamneh, T. S., Teshale, A. B., Id, Y. Y., Alem, A. Z., Ayalew, H. G., Liyew, M., Tessema, Z. T., & Tesema, G. A. (2022). Multilevel analysis of determinants of anaemia among young women (15–24) in sub-Sahara Africa. *PLOS ONE*, *17*(6), e0268129.

Gjonça, E., & Calderwood, L. (2002). *Socio-Demographic Characteristics*. *In Health, Wealth and Lifestyles of the Older Population in England: The 2002 English Longitudinal Study of Ageing*. https://scholar.google.com

Gompakis, N., Economou, M., Tsantali, C., Kouloulias, V., Keramida, M., & Athanasiou-Metaxa, M. (2007). The effect of dietary habits and socioeconomic status on the prevalence of iron deficiency in children of northern Greece. *Acta Haematologica*, *117*(4), 200–204.

Gowele, V. F., Kinabo, J., Jumbe, T., Kirschmann, C., Frank, J., & Stuetz, W. (2019). [Study from Tanzania]. *Foods*, *8*(1), 35.

Gupta, A., Sachdev, H. S., Kapil, U., Prakash, S., Pandey, R. M., Sati, H. C., Sharma, L. K., & Lal, P. R. (2022). Characterisation of anaemia amongst school-going adolescent girls in rural Haryana, India. *Public Health Nutrition,* 25(12), 3499–3508.

Ickes, S. B., Hurst, T. E., & Flax, V. L. (2015). Maternal literacy, facility birth and education are positively associated with better infant and young child feeding practices and nutritional status among Ugandan children. *The Journal of Nutrition*, *145*(11), 2578–2586.

Jape, V. W. (2017). *Patterns and Determinants of Vegetable Intake in Babati District, Tanzania [Master's thesis, University of Copenhagen].* https://scholar.google.com/

Johri, M., Subramanian, S., Kone, G. K., Dudeja, S., Chandra, D., Minoyan, N., & Pahwa, S. (2016). Maternal health literacy is associated with early childhood nutritional status in India. *The Journal of Nutrition*, 146(7), 1402–1410.

Jonker, F. A., & Van Hensbroek, M. B. (2014). Anaemia, iron deficiency and susceptibility to infections. *Journal of Infection*, *69*(S1), S23–S27.

Katenga-Kaunda, L. Z., Kamudoni, P. R., Holmboe-Ottesen, G., Fjeld, H. E., Mdala, I., Shi, Z., & Iversen, P. O. (2021). Enhancing nutrition knowledge and dietary diversity among rural pregnant women in Malawi: A randomized controlled trial. *BMC Pregnancy and Childbirth*, *21*, 1–11.

Kim, J., Shin, S., Han, K., Lee, K., Kim, J., Choi, Y., & Lee, H. (2014). Relationship between socioeconomic status and anaemia prevalence in adolescent girls based on the fourth and fifth Korea National Health and Nutrition Examination Surveys. *European Journal of Clinical Nutrition*, 68(2), 253–258.

Kinyoki, D., Osgood-Zimmerman, A. E., Bhattacharjee, N. V., Kassebaum, N. J., & Hay, S. I. (2021). Anaemia prevalence in women of reproductive age in low- and middle-income countries between 2000 and 2018. *Nature Medicine*, *27*(10), 1761–1782.

Klimek-Szczykutowicz, M., Szopa, A., & Ekiert, H. (2020). *Citrus limon* (Schenone, Dančík, Wagner, & Clemons) phenomenon: A review of the chemistry, pharmacological properties, applications in the modern pharmaceutical, food, and cosmetics industries, and biotechnological studies. *Plants*, *9*, 119. https://doi.org/10.3390/plants9010119

Kushel, M. B., Gupta, R., Gee, L., & Haas, J. S. (2006). Housing instability and food insecurity as barriers to health care among low-income Americans. *Journal of General Internal Medicine*, *21*(1), 71–77.

Lambrecht, N. J., Bridges, D., Wilson, M. L., Adu, B., Eisenberg, J. N. S., Folson, G., Baylin, A., & Jones, A. D. (2022). Associations of bacterial enteropathogens with systemic inflammation, iron deficiency, and anemia in preschool-age children in southern Ghana. PLOS ONE, 17(7), e0271099.

Lebso, M., Anato, A., & Loha, E. (2017). Prevalence of anaemia and associated factors among pregnant women in Southern Ethiopia: A community-based cross-sectional study. *PLOS ONE*, *12*(9), e0186261. https://doi.org/10.6084/m9.figshare.5616433

Lin, L., Wei, Y., Zhu, W., Wang, C., Su, R., Feng, H., & Yang, H. (2018). Prevalence, risk factors and associated adverse pregnancy outcomes of anaemia in Chinese pregnant women: A multicentre retrospective study. *BMC Pregnancy and Childbirth*, *18*, 111.

Liu, M., Li, X. Q., Weber, C., Lee, C. Y., Brown, J., & Liu, R. H. (2002). Antioxidant and antiproliferative activities of raspberries. *Journal of Agricultural and Food Chemistry*, *50*(10), 2926–2930.

Liwenga, E. T. (2003). *Food Insecurity and Coping Strategies in Semiarid Areas: The case of Mvumi in Central Tanzania*. Almqvist & Wiksell International.

Liyew, A. M., Tesema, G. A., Alamneh, T. S., Worku, M. G., Teshale, A. B., Alem, A. Z., Tessema, Z. T., & Yeshaw, Y. (2021). Prevalence and determinants of anaemia among pregnant women in East Africa: A multi-level analysis of recent demographic and health surveys. *PLOS ONE*, *16*(4), e0250560.

Lozoff, B. (2007). Iron deficiency and child development. *Food and Nutrition Bulletin*, *28*(4 Suppl), S560–S571. https://doi.org/10.1177/15648265070284s409

Mazengo, M. C., Simell, O., Lukmanji, Z., Shirima, R., & Karvetti, R. L. (1997). Food consumption in rural and urban Tanzania. *Acta Tropica*, *68*(3), 313–326. https://doi.org/10.1016/S0001-706X(97)00113-7

McLaren, S. (2022). The relationship between hemoglobin level and socio-economic indicators among women of childbearing age in South Africa: A secondary analysis of DHS data. *Ecology of Food and Nutrition*, *61*(1), 56–63.

Milman, N. T. (2020). Dietary iron intake in pregnant women in Europe: A review of 24 studies from 14 countries in the period 1991–2014. *Journal of Nutrition and Metabolism*, *2020*, 7102190.

Moshi, F. V. (2020). *Do Early Antenatal Booking Predict Maternal Services Utilization? An Analysis of Data from the 2015–16 Tanzania HIV and Malaria Indicators Survey* [Master's thesis]. https://scholar.google.com

Msuya, J., Mamiro, P. S., & Weinberger, K. (2009). Iron, zinc and β-carotene nutrients potential of non-cultivated indigenous vegetables in Tanzania. *Acta Horticulturae*, *806*, 197–202.

Mtenga, D. V., & Ripanda, A. S. (2022). A review on the potential of underutilized Blackjack (*Bidens pilosa*) naturally occurring in sub-Saharan Africa. *Heliyon*, *8*(6), e09586.

Neufingerl, N., & Eilander, A. (2022). Nutrient intake and status in adults consuming plant-based diets compared to meat-eaters: A systematic review. *Nutrients*, *14*(1), 29.

Ngimbudzi, E. B., Massawe, S. N., & Sunguya, B. F. (2021). The burden of anaemia in pregnancy among women attending the antenatal clinics in Mkuranga District, Tanzania. *Frontiers in Public Health*, *9*, 724562.

Nguyen, H. C., Chen, C. C., Lin, K. H., Chao, P. Y., Lin, H. H., & Huang, M. Y. (2021). Bioactive compounds, antioxidants, and health benefits of sweet potato leaves. *Molecules*, *26*(7), 1820.

Nti, J., Afagbedzi, S., Da-Costa Vroom, F. B., Ibrahim, N. A., & Guure, C. (2021). Variations and determinants of anaemia among reproductive age women in five sub-Saharan Africa countries. *BioMed Research International*, *2021*, 9957160.

Nyanhanda, T., Gould, E. M., McGhie, T., Shaw, O. M., Harper, J. L., & Hurst, R. D. (2014). Blackcurrant cultivar polyphenolic extracts suppress CCL26 secretion from alveolar epithelial cells. *Food & Function*, *5*(4), 671–677. https://doi.org/10.1039/c3fo60568j

Obai, G., Odongo, P., & Wanyama, R. (2016). Prevalence of anaemia and associated risk factors among pregnant women attending antenatal care in Gulu and Hoima Regional Hospitals in Uganda: A cross-sectional study. *BMC Pregnancy and Childbirth*, *16*, 76.

World Health Organization. (2003). *WHO and FAO Announce Global Initiative to Promote Consumption of Fruit and Vegetables*. https://www.who.int/news/item/03-04-2003-who-and-fao-announce-global-initiative-to-promote-consumption-of-fruit-and-vegetables

O'Toole, F., Hokey, E., McAuliffe, F., & Walsh, J. (2024). The experience of anaemia and ingesting oral iron supplementation in pregnancy: A qualitative study. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *297*, 111–119.

Pasricha, S. R., & Moir-Meyer, G. (2023). Measuring the global burden of anaemia. *The Lancet Haematology*, *10*(9), e696–e697.

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

Pronk, S., Páll, S., Schulz, R., Larsson, P., Bjelkmar, P., Apostolov, R., Shirts, M. R., Smith, J. C., Kasson, P. M., van der Spoel, D., Hess, B., & Lindahl, E. (2013). GROMACS 4.5: A high-throughput and highly parallel open-source molecular simulation toolkit. *Bioinformatics*, 29(7), 845–854.

Richards, T. J., & Rickard, B. (2020). COVID-19 impact on fruit and vegetable markets. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *68*(2), 189–194.

Saaka, M., Oladele, J., Larbi, A., & Hoeschle-Zeledon, I. (2017). Dietary diversity is not associated with haematological status of pregnant women resident in rural areas of northern Ghana. *Journal of Nutrition and Metabolism*, *2017*, 8497892.

Schenone, M., Dančík, V., Wagner, B. K., & Clemons, P. A. (2013). Target identification and mechanism of action in chemical biology and drug discovery. *Nature Chemical Biology*, *9*(4), 232–240.

Shi, H., Chen, L., Wang, Y., Sun, M., Guo, Y., Ma, S., Wang, X., Jiang, H., Wang, X., Lu, J., Ge, L., Dong, S., Zhuang, Y., Zhao, Y., Wei, Y., Ma, X., & Qiao, J. (2022). Severity of anemia during pregnancy and adverse maternal and fetal outcomes. *JAMA Network Open,* 5(2), e2147046.

Shih, M. C., Kuo, C. C., & Chiang, W. (2009). Effects of drying and extrusion on colour, chemical composition, antioxidant activities and mitogenic response of spleen lymphocytes of sweet potatoes. *Food Chemistry*, *117*(1), 114–121.

Singletary, K. (2010). Turmeric: An overview of potential health benefits. *Nutrition Today*, *45*(5), 216–225. https://doi.org/10.1097/NT.0b013e3181f1d72c

Smith, M., Marley, K., Seigler, D., Singletary, K., & Meline, B. (2000). Bioactive properties of wild blueberry fruits. *Journal of Food Science*, *65*(2), 352–356.

Smith, S. M. (2013). Determining sample size: How to ensure you got the correct sample size. *Qualitative Health Research*, *10*, 3–5.

Srinivasan, K. (2017). Ginger rhizomes (*Zingiber officinale*): A spice with multiple health beneficial potentials. *Pharma Nutrition*, *5*(1), 18–28.

Stephen, G., Mgongo, M., Hashim, T. H., Katanga, J., Stray-Pedersen, B., & Msuya, S. E. (2018). Anaemia in pregnancy: Prevalence, risk factors, and adverse perinatal outcomes in Northern Tanzania. *Journal of Pregnancy*, *2018*, 1846280.

Stevens, G. A., Paciorek, C. J., Flores-Urrutia, M. C., Borghi, E., Namaste, S., Wirth, J. P., Suchdev, P. S., Ezzati, M., Rohner, F., Flaxman, S. R., & Rogers, L. M. (2022). National, regional, and global estimates of anaemia by severity in women and children for 2000–19: A pooled analysis of population-representative data. *The Lancet Global Health*, 10(5), e627–e639.

Stoffel, N. U., Von Siebenthal, H. K., Moretti, D., & Zimmermann, M. B. (2020). Oral iron supplementation in iron-deficient women: How much and how often? *Molecular Aspects of Medicine*, *75*, 100865.

Sun, J., Wu, H., Zhao, M., Magnussen, C. G., & Xi, B. (2021). Prevalence and changes of anaemia among young children and women in 47 low- and middle-income countries, 2000–2018. *eClinicalMedicine*, *41*, 101135.

Sunguya, B. F., Ge, Y., Mlunde, L., Mpembeni, R., Leyna, G., & Huang, J. (2021). High burden of anaemia among pregnant women in Tanzania: A call to address its determinants. *Nutrition Journal*, *20*(1), 1–11.

Sunuwar, D. R., Sangroula, R. K., Shakya, N. S., Yadav, R., Chaudhary, N. K., & Pradhan, P. M. S. (2019). Effect of nutrition education on hemoglobin level in pregnant women: A quasi-experimental study. *PLOS ONE*, *14*(3), e0213982.

Teshale, A. B., Tesema, G. A., Worku, M. G., Yeshaw, Y., & Tessema, Z. T. (2020). Anaemia and its associated factors among women of reproductive age in eastern Africa: A multilevel mixed-effects generalized linear model. *PLOS ONE*, *15*(9), e0238957.

Tsai, C. W., Chen, H. W., Sheen, L. Y., & Lii, C. K. (2012). Garlic: Health benefits and actions. *BioMedicine*, *2*, 17–29. https://doi.org/10.1016/j.biomed.2011.12.002

Uyoga, S., Ndila, C. M., Macharia, A. W., Nyutu, G., Shah, S., Peshu, N., Clarke, G. M., Kwiatkowski, D. P., Rockett, K. A., Williams, T. N., & MalariaGEN Consortium. (2015). Glucose-6-phosphate dehydrogenase deficiency and the risk of malaria and other diseases in children in Kenya: A case-control and a cohort study. *The Lancet Haematology*, 2(10), e437–e444. https://doi.org/10.1016/S2352-3026(15)00152-0

Walter, T. (1994). Effect of iron-deficiency anaemia on cognitive skills in infancy and childhood. *Baillière's Clinical Haematology*, *7*(4), 815–827. https://doi.org/10.1016/S0950-3536(05)80126-X

Wasihun, A. G., Teferi, M., Negash, L., Marugán, J., Yemane, D., McGuigan, K. G., Conroy, R. M., Abebe, H. T., & Dejene, T. A. (2020). Intestinal parasitosis, anaemia and risk factors among pre-school children in Tigray region, northern Ethiopia. *BMC Infectious Diseases,* 20, 379.

Williams, T. N. (2016). Sickle cell disease in sub-Saharan Africa. *Hematology/Oncology Clinics of North America*, *30*(2), 343–358. https://doi.org/10.1016/j.hoc.2015.11.007

Zhao, F., Pang, W., Zhang, Z., Zhao, J., Wang, X., Liu, Y., Wang, X., Feng, Z., Zhang, Y., Sun, W., & Liu, J. (2016). Pomegranate extract and exercise provide additive benefits on improvement of immune function by inhibiting inflammation and oxidative stress in high-fat-diet-induced obesity in rats. *The Journal of Nutritional Biochemistry*, 32, 20–28.

Zijp, I. M., Korver, O., & Tijburg, L. B. (2000). Effect of tea and other dietary factors on iron absorption. *Critical Reviews in Food Science and Nutrition*, *40*(5), 371–398. https://doi.org/10.1080/10408690091189239

RESEARCH OUTPUTS

(i) Publications

Malley, Z. A., Sauli, E., & Martin, H. D. (2025). The impact of micronutrient-rich diets on adolescent health in rural communities. *Current Research in Nutrition and Food Science*, *13*(2), 145–158. https://doi.org/10.1234/crnfs.v13i2.2025

(ii) Poster presentation