

Paradox of Iron Deficiency Anemia Despite Adequate Iron Intake Among Women of Childbearing Age in Adjumani Refugee Settlement, Northern Uganda

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Abstract

Background:Anemia remains a major concern among women of childbearing age (WCBA) in refugee settings, driven by food insecurity, poor dietary diversity, infections, and inadequate sanitation. However, despite reported adequate iron intake, the contribution of iron deficiency anemia to overall anemia prevalence remains poorly understood, creating an important evidence gap. This study investigated: (i) dietary iron intake; (ii) contribution of iron deficiency to anemia prevalence and (iii) socio-economic and dietary factors influencing serum iron status of WCBA.

Methods:A cross-sectional survey was conducted among 462 non-pregnant WCBA. Dietary intake was assessed using a seven-day food frequency questionnaire, and daily iron intake was estimated using Harvestplus food composition tables. Hemoglobin levels were measured with a HemoCue Hb 301 analyzer, and IDA was determined by analyzing serum ferritin using Human Ferritin ELISA kit (Bio-techne company, United Kingdom), following standard procedure and manual from the manufacturer.

Results:Average dietary iron intake was not significantly different ($p \leq 0.05$) from recommended daily intake (RDI) of iron except for one refugee settlement. The intake of iron was largely from plant sources. Overall anemia prevalence was 34.4%, with a mean hemoglobin concentration of 10.76 g/dL. Iron deficiency anemia (IDA) accounted for 37% of anemia cases, with variation across settlements: Adjumani East recorded 58% prevalence compared to 17% in Adjumani West. Socio-economic factors including education, income-generating activities, and household income significantly influenced serum ferritin levels ($p < 0.05$). Food consumption patterns revealed reliance on cereals and legumes, with minimal intake of iron-rich animal products.

Conclusions: Despite reported iron intake near recommended levels, iron deficiency anemia remained high, highlighting the poor bioavailability of plant-based iron sources. Nutrition interventions should prioritize dietary diversification, encouraging inclusion of animal-source foods and enhancers of iron absorption. Strengthening economic opportunities for refugee women may improve access to nutrient-rich foods and reduce anemia prevalence. These findings underscore the paradox of adequate intake but persistent deficiency, offering novel insights for targeted nutrition strategies in humanitarian contexts.

INTRODUCTION

Anemia remains a major global public health challenge, affecting approximately two billion people worldwide and disproportionately impacting women of childbearing age (WCBA) [1–3]. The condition arises when the number of red blood cells or their oxygen-carrying capacity is insufficient to meet physiological needs, leading to adverse health outcomes including fatigue, impaired cognitive function, reduced productivity, and increased risk of maternal and perinatal mortality [4,5]. In low- and middle-income countries, the burden of anemia is particularly high due to the combined effects of inadequate dietary intake, infectious diseases, and socioeconomic constraints [6–8]. Sub-Saharan Africa bears a substantial share of this burden, with prevalence estimates exceeding 60% in some populations [9,10]. In Uganda, approximately one-third of WCBA are affected by anemia, with even higher rates reported in vulnerable populations such as refugees [11]. These figures highlight the persistent and multifactorial nature of anemia in resource-limited settings.

Iron deficiency is widely recognized as the leading cause of anemia, accounting for a significant proportion of cases globally [12,13]. Iron plays a critical role in hemoglobin synthesis, oxygen transport, and cellular metabolism, and its deficiency can lead to impaired physiological and cognitive functioning [14,15]. However, anemia is a multifaceted condition that may also result from deficiencies in other micronutrients such as folate, vitamin B12, and vitamin A, as well as from infections including malaria, HIV, and helminth infestations [3,5]. The relative contribution of iron deficiency to overall anemia varies across settings, depending on dietary patterns, disease burden, and environmental conditions

[13,16]. Accurate assessment of iron deficiency anemia (IDA) therefore requires the use of biochemical indicators such as serum ferritin, which reflects body iron stores, although its interpretation may be influenced by inflammation.

Dietary intake is a fundamental determinant of iron status, yet the quantity of iron consumed does not necessarily reflect the amount absorbed and utilized by the body [17,18]. Iron exists in two forms in the diet: heme iron, primarily derived from animal-source foods, and non-heme iron, found in plant-based foods [19]. Heme iron is more efficiently absorbed, whereas non-heme iron absorption is highly variable and influenced by dietary factors [15,20]. Diets dominated by plant-based staples, common in many low-income and humanitarian settings often contain high levels of absorption inhibitors such as phytates and polyphenols, which reduce iron bioavailability [15,21]. Conversely, enhancers such as vitamin C and animal proteins can improve non-heme iron absorption [22]. As a result, populations consuming predominantly plant-based diets may meet recommended dietary iron intake levels quantitatively while remaining at risk of iron deficiency due to poor bioavailability [19].

Refugee populations are particularly vulnerable to such nutritional challenges. In many humanitarian contexts, food systems are heavily reliant on food aid or limited market access, resulting in diets that lack diversity and are dominated by cereal-based staples [23,24]. Although recent shifts toward cash-based assistance have improved access to food in some settings, economic constraints continue to limit the consumption of nutrient-dense and animal-source foods [25,26]. In Uganda, which hosts one of the largest refugee populations in Africa, settlements such as those in Adjumani district are characterized by high levels of food insecurity and dependence on external assistance [27]. Previous assessments in these settings have reported high prevalence of anemia among WCBA [13,28–30], yet most studies have relied primarily on hemoglobin measurements without adequately linking dietary intake to biochemical indicators of iron status.

An emerging concern in nutrition research is the apparent paradox between adequate reported dietary iron intake and persistent high prevalence of iron deficiency anemia. This discrepancy may be explained by factors such as low dietary diversity, poor iron bioavailability, underlying infections, and socioeconomic determinants that influence both diet quality and health outcomes [1,13,30]. However, empirical evidence examining this relationship in refugee settings remains limited, particularly studies that integrate dietary assessment with biochemical measurements such as serum ferritin. Therefore, this study, using Adjumani refugee settlements in Northern Uganda as a case study, aimed to (i) assess dietary iron intake among women of childbearing age, (ii) determine the contribution of iron deficiency to the overall burden of anemia using biochemical indicators, and (iii) identify socio-demographic and dietary factors associated with iron status. By addressing both dietary and biochemical dimensions of iron nutrition, this study provides critical insights into the underlying drivers of anemia in humanitarian contexts and informs the design of targeted nutrition interventions.

MATERIALS AND METHODS

Study area

The study was carried out in Adjumani district. It's among the nine districts in West Nile region that is hosting South Sudanese refugees. It comprises of a total population of 439,900 among which 207,500 are refugees and 18.3% (37,350) of these are women of childbearing age [27,31]. This district was selected because it's one of the refugee hosting districts with a high prevalence of food insecurity despite the existing interventions [27].

Research design

This study employed a cross-sectional design consisting of a survey on dietary iron intake and laboratory analysis for iron status of women of childbearing ages. Laboratory examination of blood samples was used to determine serum iron

status and iron deficiency anemia.

Study Population

The study population comprised of WCBA because they are more vulnerable to iron deficiency anemia. Only registered, validated refugees and those willing to participate met the criteria for participation in the study. For the women to qualify to be recruited for the study, one had to be non-pregnant during the study and should have had their last menstrual period within three weeks period since the likelihood of them being pregnant was considered low. In addition, only refugees were considered, and they should have stayed in the settlement for a period of at least 3 months. Finally, for women below 18 years, only those with children were considered for the study as a proof that they were of reproductive ages. Pregnant women were not considered since they were taking iron supplements which would have given results not reflective of their dietary iron intake. In addition, Lactating women were excluded as their needs for iron would be higher than the other WCBAs. Furthermore, non-refugee WCBAs were not considered and WCBA who had stayed in the settlement for less than 3 months were also excluded since they had not been exposed to the dietary iron intake situation in the settlement.

Sampling Procedure

Adjumani district was purposively selected since its one of the districts in West Nile hosting the highest number of refugees with the highest anemia prevalence. Eight out of the 19 refugee settlements in Adjumani district were selected using simple random sampling. Furthermore, only one block was randomly selected from each of the 8 settlements. Within the selected block a cluster was chosen using simple random sampling. Study participants were selected from a sampling frame containing households with WCBA in the different clusters that were obtained from the Village Health Teams (VHTs).

Data Collection

During data collection, each team comprised of the following people: a laboratory assistant who was responsible for hemoglobin anemia screening & blood sample collection, and a nutritionist who administered the questionnaire on socio-demographic and dietary assessment, adopted from Motuma et al., [25] with modification. Then one VHT responsible for translating the questions from English to the local language.

Assessment of dietary iron intake among women of childbearing age

A food frequency questionnaire consisting of standard 10 groups for women of childbearing age was used to capture the frequency of consumption of the food groups by the study subjects for a period of 7 days, adopted from Motuma et al., [25] with modification. Estimated portion sizes in grams were also captured and was used to calculate the daily iron intake with the aid of harvest plus food composition tables [32].

Determination of iron deficiency anemia among women of childbearing age

Anemic screening of study participant in the field

To determine dietary iron deficiency anemia, anemia screening was conducted for all selected participants using a Hemoglobin concentration was measured using the HemoCue Hb 301 analyzer, which is factory-calibrated against the hemiglobincyanide (HiCN) reference method and does not require further calibration [33]. Internal quality control was

ensured through built-in self-testing and periodic use of control samples. Anemia was defined as Hemoglobin Concentrations of <12.0g/dl for non-pregnant women of childbearing age (15-49years). The anemia status was classified using the WHO cut offs (Table 1).

Table 1: Categories of anemia among women of reproductive ages based on cut offs for levels of hemoglobin.

Sample category for non-pregnant WCBA	Cut HB level
Severe anemia	< 8.0g/dl
Mild anemia	11.0-11.9g/dl
Moderate anemia	8.0-10.9g/dl
Normal anemia status	>12g/dl
General anemia	<12g/dl

Source: WHO [34]

Upon screening, blood samples were collected (as in sub-section 2.4.3.2) from the study group that were found to be anemic based on the Hemoglobin cuts offs for further investigation using ferritin levels as an iron biomarker. Serum iron levels were determined as a biomarker of iron in the blood using ELISA method according to the previous study [35].

Collection of blood samples to determine serum iron status

During household interviews, the samples of participants who were identified as anemic during screening were collected for further analysis to determine the serum ferritin levels using DuoSet ELISA kit batch number DY3541-05 (Bio-technie Company, United Kingdom). The amount of blood that was drawn from the left arm of each participant was 4mls using 5 ml syringes and was placed in Vacuatainer bottles and stored in the cool boxes for a maximum of 6 hours while still in the field before they were transported to the nearest health facilities for storage in a refrigerator under -4°C. The samples were stored in the freezer (-4°C) for a maximum of 2 days upon which they were transported to the multifunctional lab at Gulu University for final analysis. Cool and freeze storage at all points was done to ensure that the quality of the blood samples was not compromised to be able to produce accurate results which were a true reflection of the client iron levels.

Safety during Sample collection

To ensure safety during sample collection, the health workers followed the standard operating procedures for blood sample collection. Trained laboratory medical personnel were used to draw blood from the participants, subjects were informed about the procedure prior to sample collection which aimed at preparing them mentally to reduce risks of invasive accidents during pricking of the participants. Personal Protective Equipment (PPEs) such as gloves, masks and face shields were used to prevent disease transmission.

Laboratory procedure for serum ferritin (iron) determination

The serum ferritin levels were estimated using Enzyme-Linked Immunosorbent Assay (ELISA) Method. The DuoSet ELISA kit used was purchased from Bio-technie Company, United Kingdom, with a batch number of DY3541-05. This method was selected because of its high sensitivity, accuracy and specificity. This was realized when three methods were compared such as ELISA, Cobas e411 and Coba Integra in analyzing serum ferritin levels, it was found out that there was no significant statistical difference between ELISA and Cobas e411 while there were significantly higher values from Cobas Integra 400 method [35]. In this study, the steps used in analyzing serum ferritin levels included the following:

Plate Preparation was done which involved: Initially, the capture antibody was diluted to a working concentration in Phosphate-buffered saline (PBS) without any carrier protein. Subsequently, 100 µL of the diluted capture antibody was added to each well of a 96-well microplate. The plate was sealed and left to incubate overnight at room temperature. Afterward, the contents of each well were aspirated, and a buffer was used to wash each well. This washing process was repeated two more times, resulting in a total of three wash cycles. To perform the washes, each well was filled with 400 µL of wash buffer using a squirt bottle.

To block the plates, 300 µL of reagent diluent was added to each well and incubated at room temperature for one hour, as described by Dahman et al., [35].

Subsequently, plate aspiration was performed to prepare them for sample addition. The assay procedure involved the following steps: 100 µL of sample or standards in reagent diluent were added per well, covered with an adhesive strip, and incubated for 2 hours at room temperature. Afterward, plate washing was conducted. Following the washing step, 100 µL of the detection antibody, diluted in reagent diluent, was added to each well, covered with a new adhesive strip, and incubated for an additional 2 hours at room temperature. Plate aspiration was repeated once again. Next, 100 µL of the working dilution of streptavidin-HRP B was added to each well, covered, and incubated for 20 minutes at room temperature, followed by another round of washing/aspiration. Subsequently, 100 µL of substrate solution was added to each well and incubated for 20 minutes at room temperature, away from direct light. Finally, 50 µL of stop solution was added to each well, and the plate was gently tapped to ensure thorough mixing. The optical density of each well was determined immediately using a microplate reader set at 450nm. For the calculation of results, duplicate readings for each standard, control, and sample were averaged, and the average zero standard optical density was subtracted. A standard curve was constructed by plotting the mean absorbance for each standard on the y-axis against the concentration on the x-axis, with a best-fit curve drawn through the points on the graph. Afterward, the data was linearized by plotting the logarithm of the human ferritin concentrations against the logarithm of the optical densities, and the best-fit line was determined through regression analysis.

Assessment of factors associated with serum iron status

Data on factors linked to serum iron levels was collected from the respondents using a pre-tested questionnaire adopted from Temesgen et al., [36] with modification and was administered and filled in by trained enumerators. These included demographic data (e.g., age, education levels) and dietary data (e.g., frequency of food consumption) predicted to affect the levels of iron in the body. Analyses were made to ascertain if these factors were associated with participants levels of iron in the blood. All the data collected was checked and verified for accuracy, completeness, and eligibility daily in the field and upon returning.

Data Analysis

The data analysis was performed using IBM SPSS version 25 (Statistical Package for Social Scientists). Preceding the analysis of data, a process of data cleaning was conducted to improve the overall quality of the data. The analysis of data was done per objective as follow:

Dietary iron intake by women in childbearing age in Adjumani Refugee Settlement

The captured portion size estimates from the Food frequency questionnaire were recalculated into daily iron intake using predetermined formulas from the food composition tables. This objective was analyzed in the following parts (i) socio-

demographic characteristics, frequency of commonly consumed foods, and estimated weekly iron intakes were summarized using descriptive statistics particularly frequency, percentage, mean, and standard deviation (ii) comparison of daily iron intake to recommended daily iron intake was done using one sample t-test and (iii) factors influencing the dietary iron intake was analyzed using multilinear regression.

A Pearson correlation analysis was conducted before performing regression analysis. This was done to remove variables that were highly correlated [37] ($r > 60\%$).

Assessment of the contribution of iron deficiency anemia to total anemia

Descriptive statistics and graphs were utilized to summarize iron concentration of anemic participants. One sample t-test was used to compare the mean serum iron concentration with the WHO recommended cut off (15 µg/L) of iron concentration in women in childbearing age.

Determination of impact of dietary and socio-demographic factors on serum ferritin status of women of childbearing age in Adjumani Refugee Settlement

Factors influencing the serum ferritin were analyzed using multilinear regression and the regression model utilized. A Pearson correlation analysis was conducted before performing regression analysis. This was done to remove variables that were highly correlated ($r > 60\%$).

RESULT

Socio-demographic statistics of women of childbearing age sampled from Adjumani refugee settlement

Table 2 presents the sociodemographic characteristics of 462 Women of Childbearing Age (WCBA) residing in Adjumani Refugee Settlement who were targeted during the study. The majority of respondents had been married (81%), while smaller proportions had been single (11.7%), widowed (4.3%), or divorced (3%). Educational attainment had been generally low: half had completed primary education, one-third had no formal education, and only 1.5% had reached tertiary level. Occupationally, informal employment had been the most common (42.9%), followed by farming (39%). Business (12.6%) and formal employment (5.6%) had accounted for smaller shares (Table 2). Food sources had been dominated by donations (74.7%), with fewer households relying on own production (16.9%) or purchase (8.4%) (Table 2).

Income-generating activities had largely centered on farming (49.4%), while 25.1% had reported no activity at all. Business (15.4%), formal employment (8.7%), and fishing (1.5%) had been less frequent.

On average, households had earned 100,837 UGX, though income levels had varied widely (SD = 136,196). The mean age of respondents had been 31 years (SD = 8.8) (Table 2). Each household had typically had one income earner (mean = 1, SD = 1.18), and household sizes had averaged eight members (SD = 3.49) (Table 2).

Table 2. Socio-demographic characteristics of Women of childbearing ages sampled from Adjumani Refugee Settlement

Socio-demographic characteristics		N	Proportion (%)	Mean	Std deviation
Marital status	Single	54	11.7		
	Married	374	81		
	Divorced	14	3		
	Widowed	20	4.3		
Education Level	Primary	231	50		
	Secondary	70	15.2		
	Tertiary	7	1.5		
	No formal education	154	33.3		
Occupation	Farming	180	39		
	Business	58	12.6		
	Formal employment	26	5.6		
	Informal employment	198	42.9		
Source of food	Own production	78	16.9		
	Purchase	39	8.4		
	Donation	345	74.7		
Income generating activity	Business	71	15.4		
	Farming	228	49.4		
	Formal employment	40	8.7		
	None	116	25.1		
	Fishing	7	1.5		
Average Household income (UGX)				100837	136196
Age (years)				31.08	8.805
People Earning Income				1	1.18
Household Size				8	3.488

UGX = Uganda shillings, (N = 462), N = number

Prevalence of iron deficiency anemia among refugee women sampled from Adjumani settlement

Table 3 presents proportion of anemia among WCBA within Adjumani refugee settlement.

Table 3: Prevalence of anemia among women of childbearing age

Settlement	Mean Hb (g/dL)	Mean Hb among anemic sample (g/dL)	Proportion of anemia (%)	MFSC (mg/L)	Proportion with IDA (%)
Overall	12.50 ^a	10.76	34.40	8.78	37.24
Adjumani East	12.42 ^a	10.53	29.98	7.86	57.78
Adjumani West	12.20 ^a	10.70	38.80	8.08	16.70

N = 462, WCBA = Women in Childbearing Age, Hb = Hemoglobin, MFSC= Mean Ferritin Serum Concentration, and IDA = Iron Deficiency Anemia

Overall, 34.4% were anemic with an average hemoglobin of 10.76g/dL (Table 3). The proportion of anemia was higher in Adjumani West compared to the overall proportion of the settlement. Regrading iron deficiency, Adjumani East had a higher proportion (about 58%) of IDA compared to that observed in overall settlement (about 37%) and Adjumani West (approximately 17%), with a mean ferritin serum concentration of 7.86mg/L (Table 3).

Dietary iron intake in Adjumani Refugee Settlement compare recommended threshold of iron intake among women of children bearing age

Frequency of weekly consumption of foods rich in iron

Table 4 presents an analysis of the frequency of consumption of common foods, including cereals, root and stem tubers, legumes, nuts and oil seeds, dairy products, meat, fish and poultry, eggs, vitamin A-rich vegetables and fruits, green leafy vegetables, and other fruits. Plant-based foods were found to be more frequently consumed than animal-based foods.

Table 4: Weekly consumption of different sources of iron by women of childbearing age sampled from Adjumani Refugee settlement

Food items		Frequency consumption per week (%)					Mean frequency of consumption (days)	Std. Deviation
		Never	Once	2-3 times	4-6 times	Daily		
Cereals	Sorghum	26.400	4.100	12.100	3.2	54.1	2.55	1.733
	Millet	82.000	4.800	5.200	1.1	6.1	0.46	1.119
	Maize	18.000	12.300	22.700	3.2	43.7	2.42	1.565
Root & stem tubers	Potatoes	78.000	9.500	8.400	0.4	2.8	0.39	0.879
	Cassava	57.800	20.800	13.800	1.1	6.7	0.78	1.147
	Yams	79.200	5.500	5.000	5.0	5.0	0.41	0.970
Legumes	Beans	14.300	13.600	41.300	3.9	26.8	2.15	1.342
	Garden peas	95.700	2.800	1.100	1.1	0.4	0.07	0.369
	Pigeon peas	60.200	18.600	18.600	0.6	1.7	0.65	0.923
Green leafy vegetables	Spinach	89.200	6.300	4.300	4.3	0.20	0.16	0.496
	Apparanthus (Dodo)	78.100	20.100	1.500	1.3	0.20	0.24	0.489
	Cabbage	69.300	23.800	6.500	1.5	0.40	0.39	0.648
	Cow pea leaves	27.700	25.500	39.000	6.5	6.3	1.33	1.089
	African spider plant	94.400	4.800	0.600	1.5	0.20	0.07	0.322
Animal sources	Fish	37.200	23.400	34.00	2.200	2.600		
	Milk	67.700	25.300	5.400	0.200	0.600		
	Chicken	93.700	5.800	0.200	0.000	0.200		
	Egg	88.500	8.700	2.600	0.200	0.000		
Vitamin A-rich fruits	Mangoes	93.300	4.800	0.400	0.4	1.50	0.12	0.543
	Papaws	80.100	15.200	3.500	3.5	1.30	0.27	0.651
	Carrots	98.100	1.700	0.200	1.7	0.20	0.02	0.160

(n = 462), std = standard

Estimated weekly intake of iron from foods commonly consumed by women of childbearing age in Adjumani Refugee settlement

Table 5 presents the estimated dietary iron intake from common foods. Sorghum exhibited a dietary iron intake about 7mg/week, while the ladies' fingers (Okra), ground nut, cowpea leaves, tomatoes, and bean-based diets showed a dietary iron intake below 1mg/week. Nonetheless, the consumption of dietary iron derived from simsim, Osobi, okra, and pigeon peas did not exhibit a significant difference at a p-value of 0.05.

Table 5: Mean weekly dietary iron intake from food items commonly consumed by women in childbearing age in Adjumani refugee settlement

Consumed foods	Mean (mg/week)	Std deviation
Sorghum	7.20 ^a	0.282
Maize	3.96 ^b	0.007
Beans	0.56 ^{de}	0.028
pigeon peas	0.38 ^{gf}	0.014
Ground nut	0.16 ^c	0.007
Simsim (sesame seeds)	1.03 ^{gf}	0.007
Cowpea leaves	0.23 ^{gf}	0.014
Tomatoes	0.04 ^g	0.009
Okra	0.13 ^{gf}	0.007

Means with different letter in the same column are significantly different at $p \leq 0.05$ (n = 462), std = standard

Comparison of daily iron consumption to the recommended threshold of iron intake among women of children bearing age

Comparison of total mean daily iron intake of study participants to recommended daily intake of iron for women in childbearing age in Adjumani Settlement is presented in Table 6.

Table 6: Comparison of total mean daily iron intake of study participants to recommended daily intake of iron for women in childbearing age

Settlements	MDI (mg/day)	MD	p-Value
Adjumani East	20.29	2.71	0.027**
Adjumani West	17.12	-0.88	0.097
Overall	17.76	-1.04	0.417

MD = Mean difference from recommended daily iron intake for WCBA of 18mg/day (34), ** = shows significance of 5%, MDI = Mean Daily Intake.

Overall, the mean iron intake by women of childbearing was approximately 17.76 mg/day which was not significantly different from the WHO recommended daily allowance (RDA) for this age category of 18.0mg/day. There were variations across the settlements with Adjumani East having highest iron intake of about 20 mg/day and Adjumani West with the lowest average iron intake of 17.12mg/day.

Dietary and socio-demographic predictors of IDA among women sampled from Adjumani refugee settlement

Table 7 presents the result of predictors of IDA among women. IDA status was impacted by various socio-economic factors.

Table 7: Predicators of IDA among women in childbearing age in Adjumani

Predictors		Coefficients		p-Value
		B	Std. Error	
Age (year)		0.031	0.062	0.623
Marital Status		0.302	0.868	0.729
level of Education		-5.017	0.463	0.033**
Sorghum consumption		-0.338	0.693	0.026**
Total daily iron intake		-6.390	0.432	0.022**
Number of people earning some income		-0.317	0.730	0.676
Income generating activity	Farming	5.07	2.48	0.032**
	Bricklaying	8.06	10.262	0.433
	Fishing	-17.22	14.24	0.228
	Business	3.45	3.37	0.309
	Formal Employment	-7.22	5.98	0.229
Estimated monthly income		-2.16	0.000	0.029**

** shows significance of 5%, B = coefficient

The results showed several predictors with a significant relationship to iron deficiency anemia (IDA) among women of childbearing age in Adjumani (Table 7). Level of education (**B = -5.017, p=0.033**), sorghum consumption (**B = -0.338, p=0.026**), total daily iron intake (**B = -6.390, p=0.022**), and estimated monthly income (**B = -2.16, p=0.029**) significantly and negatively predicted IDA (**p =0.05**). However, farming as an income-generating activity (**B = 5.07, p=0.032**) positively and significantly predicted IDA among WCBA as seen in Table 7.

DISCUSSION

Dietary iron intake by women in childbearing age in Adjumani Refugee Settlement

Anemia is a big threat to global population of women of childbearing age (WCBA), elderly, and children [7]. This challenge is attributed to inadequate intake of iron rich foods, arising from limited diets [36], a situation that can be worsened by compromised access to diverse food by displaced population in refugee settlements. Thus, from this study, it was evident that the majority of WCBA consumed plant-based foods more frequently than animal-based foods. This is similar to findings by Muggaga et al., [38] who reported that consumption of plant-based foods such as starchy staples, dark green leafy vegetables, legumes, nuts and seeds was higher than intake of animal-based foods. The overreliance on

plant-based foods could be attributed to lower purchasing power and relief dependency syndrome. The high intake of plant-based foods may provide adequate amounts of fiber, antioxidants, and phytochemicals that can modulate the gut microbiota, lower inflammation, improve metabolic parameters and reduce the risk of chronic diseases. However, plant-based diets may also pose some challenges, such as ensuring adequate intake of micronutrients like iron by lowering its bioavailability, which is essential for oxygen transport and cellular metabolism. This implies that over reliance on starchy plant-based food sources could lead to lower dietary iron intake. This can be adduced to the fact that majority of common plant-based foods consumed like sorghum, maize have low concentrations of iron. Therefore, the findings suggest that most of the iron-rich plant foods, such as fortified cereals, beans and lentils should dominate the food ration given to refugees. In addition, the low dietary iron intake could be attributed to limited diets as seen with low consumption of animal-based diets rich in Iron [36]. According to Medina et al., [39], low frequency of consumption of animal-based foods, particularly meat products among WCBA in refugee settlements is associated with high rates of anemia. Animal sources of iron, such as meat, poultry, and fish, have higher bioavailability and absorption rates than plant sources, such as beans, lentils, and leafy greens [40]. However, because of the constrained affordability of animal products, primarily due to low estimated average monthly income (Table 2), refugees often depend on what is available and accessible, which is plant-based foods (Table 3) as their primary source of nutrition. It is worth noting that these plant-based foods generally have lower iron bioavailability [41], and may need to be traditionally processed to enhance bioavailability. Hence, it is imperative to provide refugees with education on basic traditional methods of food processing. These techniques have the potential to improve the bioavailability of iron in plant-based food sources [42], thereby aiding in the elevation of iron levels in the bloodstream and the prevention or treatment of anemia.

Given that several factors influence the intake of micronutrients by WCBA, the observed positive influence of income generating activities - farming and fishing on iron consumption can be attributed to possibility of having increased dietary diversity for households with such economic activities [43]. The observed results are in line with the findings by Muggaga et al., [38] who showed that employment status (occupation) influenced consumption of nutrients by WCBA. The observed lack of significant influence of age, method of food acquisition, and household size on iron intake however contradicts with findings by Muggaga et al., [38] who highlighted otherwise.

Assessment of the contribution of iron deficiency anemia to total anemia

Proportion of women with anemia from Adjumani refugees' settlement

Anemia is a common health problem among refugees, especially in children and women [44]. According to a study by Teketelew et al., [45], anemia can affect up to 70% of refugees in some settings, due to factors such as malnutrition, infections, and poor sanitation. The prevalence and types of anemia may vary depending on the region, the camp conditions, and the age group of the refugees [46]. Study by Mutua et al., [47] reported that hemoglobinopathies were more frequent among refugees from Africa and Asia resettled in Germany. As per the present study, the overall prevalence of anemia among women in childbearing age (WCBA) was 34.4%. According to the cut off values established by the World Health Organization (WHO), the prevalence of overall anemia among WCBA of Adjumani refugee settlements in this study is considered to be a moderate public health issue [48]. Although the prevalence of overall anemia (34.4%) reported in this study was above the WHO recommended threshold, is the prevalence was lower compared to the rates reported in other studies among refugees. For instance, a study conducted in South Sudanese refugees in Pugnido, western Ethiopia, reported a prevalence of 36.1% [8]. Similarly, Palestinian refugees in the occupied Palestinian Territory had a prevalence of 38.6% [49]. Among South Sudanese refugees living in camps in Uganda, the prevalence was 36.3% in 2016 [50], and in Malaysia, it was 35.0% [8]. However, it should be noted that the prevalence in this study was higher than the findings of a study conducted in Southeast Ethiopia, which reported a prevalence of 27.9%

[30]. The observed variation in results could potentially be attributed to differences in timing and methodology [51]. For instance, the studies examining South Sudanese refugees in Pugnido, western Ethiopia, and Palestinian refugees in the occupied Palestinian Territory were conducted at different facilities in 2015 and 2006, respectively. On the other hand, the study conducted in Southeast Ethiopia focused on pregnant women residing in specific facilities. The Malaysian study had a similar focus as the present study, examining the residential population. However, it is important to note that there are additional differences between the two contexts. Displaced individuals of the Malaysian study may not have had equal access to food aid and other facilities compared to refugees in the present study [52].

According to the settlement data, settlements in Adjumani West exhibited a higher proportion of anemia as compared to Adjumani East as well as the overall proportion for all settlements. This shows significant variation in anemia prevalence among women in different regions or locations. The prevalence of anemia in Eastern Sudan, was found to be 52.4% [53]. Similarly, in Wolayta Sodo Town, Southern Ethiopia, the prevalence was 60% (36). In Karnataka, India, the prevalence was 50.4% [54], and in West Algeria, it was 49.5% [55]. These findings highlight the significant burden of severe anemia in WCBA across different geographical locations. For the refugees in Uganda, a study conducted in 2015 examined South Sudanese refugees living in refugee camps in Uganda, where severe anemia accounted for 89.2% of cases [56]. Similarly, a study conducted in Southeast Ethiopia found that severe anemia constituted 55% of cases [8]. Additionally, among South Sudanese refugees in the New Caseload of Uganda, 86.2% of cases were classified as severe anemia [57]. There are potential factors that may have contributed to inconsistencies in the study conducted among Sudanese refugees residing in refugee camps in Uganda. One such factor is the timing [29] of the present study, which took place in 2023. Additionally, it is worth noting that the present study was not conducted within a facility-based setting compared to studies. The study conducted in Southeast Ethiopia was based on a small sample size and focused exclusively on facilities, excluding individuals who were refugees. Different cut-off points were utilized in studies conducted on Palestinian refugees in occupied Palestinian Territory and Kakamega, Eastern Sudan where severe cases were defined as having a score greater than 10.9 [58]. However, iron deficiency is the main cause of anemia among refugees' population, yet Hb (hemoglobin) score may not provide an accurate representation of the issue. This is because low Hb levels can be attributed to various other factors besides iron deficiency. Hence, section 5.2.2 offers a further understanding of anemia because of iron deficiency.

Prevalence of iron deficiency anemia in Adjumani refugee settlement

Iron deficiency is a prevalent and significant health issue that frequently affects women in childbearing age [7], particularly in refugee settings characterized by limited access to sufficient nutrition and healthcare resources [46]. Based on data provided by the World Health Organization, a significant proportion of women aged 15-49 years, experienced anemia [59]. Notably, the African region exhibited the highest prevalence of anemia [60], with a rate of 60.2%. The current study revealed that approximately 37% of women in childbearing age who were anemic presented with iron deficiency anemia (IDA), showing that IDA contributed to 37% of the anemia cases reported among the study participants. This finding may be attributed to the low dietary diversity [61,62] observed in the study, as it was observed that the most frequently consumed food sources were predominantly plant-based with low amounts of iron. It is important to note that plant-based foods have a significant presence of antinutritional factors [63], which can potentially hinder the bioavailability of non-heme iron [64]. This suggests that a reduced amount of non-heme iron will be absorbed, resulting in an insufficient supply to meet the daily iron requirement. Consequently, the body may experience a deficiency in iron necessary for the production of hemoglobin [4], the protein responsible for transporting oxygen in the bloodstream. This leads to a decrease in the delivery of oxygen to the tissues and organs, resulting in symptoms such as fatigue, weakness, pallor, dyspnea, and heightened vulnerability to infections [65].

The overall serum ferritin concentration of women in childbearing age was significantly below the recommended daily iron requirement. A lower concentration of serum ferritin may have detrimental effects on both maternal and fetal health

[65,66]. These effects may include an increased risk of preterm delivery, low birth weight, and perinatal mortality [3]. The current study's findings indicate a higher prevalence of iron deficiency anemia (IDA) among women of childbearing age compared to previous studies conducted by Fite et al., [67] and Pobee et al., [28] in Eastern Ethiopia and Ghana, respectively. The disparities in dietary practices, sociocultural variations, and iron absorption could potentially contribute to the elevated prevalence of iron deficiency in the study done in Eastern Ethiopia. Moreover, the utilization of community-based selection, as opposed to solely relying on women presenting to healthcare facilities as applied in the study done in Ghana, could be responsible for the findings of the current study. However, there is a growing body of evidence suggesting that the percentage of anemia attributed to iron deficiency (ID) varies depending on geographical location, the burden of infectious diseases, and the prevalence of other causes of anemia [52]. This is supported by the findings of the current study, which observed variations in serum ferritin concentration of the sampled WCBA from different settlements within Adjumani district. This suggests that interventions aimed at reducing IDA should consider the geographical context prior to implementation to optimize their effectiveness.

However, anemia is a medical condition that impacts the production and functionality of red blood cells, which play a crucial role in transporting oxygen throughout the body [3]. There are numerous potential causes of anemia, with iron deficiency being among them [28]. Based on recent current study findings, it has been determined that iron deficiency is not the sole factor contributing to the occurrence of anemia, a medical condition characterized by impaired red blood cell production. Other factors, such as nutritional deficiencies, could have been identified as significant contributors [54]. The other contributing factors may include infections, inflammation, genetic disorders, as well as instances of blood loss [59]. It is imperative to accurately diagnose the root cause of anemia prior to initiating any treatment. In order to address this issue, it is necessary to enhance the diagnosis and classification of anemia through the utilization of standardized methods and criteria [2]. Additionally, it is imperative to conduct population-based surveys and studies to evaluate the prevalence and severity of iron deficiency anemia (IDA), along with its associated risk factors and consequences. The inclusion of such information would greatly contribute to the development and implementation of impactful interventions aimed at preventing and treating iron deficiency anemia (IDA), ultimately leading to improved health outcomes and overall well-being among women of reproductive age. However, the associated risk factors of anemia among women in childbearing age in a refugee setting is unclear, and the section 5.3 provides more insight about such information.

Influence of dietary and socio-demographic factors related to serum ferritin status of women of childbearing age

Serum ferritin serves as a valuable biomarker for assessing both iron status and inflammation [68]. It is important to consider that this biomarker can be influenced by several sociodemographic factors [69], including age, gender, ethnicity, and migration status. The objective of this study was to examine the impact of various factors on the serum ferritin concentration of refugees who have been resettled in Uganda, a developing country. Based on the findings of Milman et al., [70], it was observed that there was a significant increase in serum ferritin concentration with age in women in childbearing age. The findings of the study align with the findings of the current study, although the results of the current study were not statistically significant (Table 8). In contrast, agriculture serves as a primary source of income for numerous refugees. As per report by WHO [71], it was observed that farming exhibited a significant positive correlation with serum ferritin concentration in both refugee camps located in Uganda and Kenya. The findings of this study, as presented in Table 8, are consistent with the report. This consistency may be attributed to an increase in purchasing power [72]. The results indicate that farming could potentially have a positive impact on the serum ferritin concentration of refugees. This may be attributed to increased availability of iron-rich foods or a decrease in exposure to infections that hinder iron absorption [15]. In contrast, this study identified a negative impact of estimated monthly income with serum ferritin concentration of refugees which could be attributed to potential mismanagement of income whereby most of the income is spent more on food items like alcohol resulting from stress and psychological factors associated with financial

challenges within refugee settings [73]. These factors may impact iron metabolism [15], although the precise mechanisms involved are intricate and not yet comprehensively understood. This study presents findings that are in contrast to the research conducted by Hailu et al., [72] on non-refugee women in Ethiopia who noted that the women with low-income face challenges in accessing nutritious diets, which can result in poor eating habits and potentially contribute to anemia. There is no direct correlation between education and serum ferritin concentration. However, education can have an indirect influence on serum ferritin concentration through various mechanisms, such as enhancing knowledge about nutrition [69]. According to the findings of this study, it was observed that individuals with a non-formal education background exhibited a notable adverse effect on their serum ferritin concentration (Table 8). This outcome may be attributed to the limited understanding of nutrition among refugees [74]. This suggests that it is important to prioritize nutrition education for women of childbearing age. Therefore, nutrition interventions in refugee contexts should incorporate nutrition education as a component of their programs. Hence, this analysis may uncover underlying variables that contribute to the susceptibility and severity of iron deficiency, along with potential strategies to enhance the management of anemia.

CONCLUSION

Women in childbearing age in Adjumani refugee settlement tend to consume starchy plant-based food sources more frequently than animal-based food sources. Because of heavy reliance on plant foods such as cereals and legumes, their dietary iron intake was significantly below the recommended daily allowance of iron. The study generates additional evidence that income generating activities within the context of refugees play a significant role in positively predicting dietary iron intake.

The prevalence of anemia in the Adjumani refugee settlement can be classified as mild, although this varies among the different settlements within Adjumani district. Women from the Adjumani West settlements demonstrated a higher severity of anemia. The prevalence of anemia upon field screening was 34.4%. The study further shows that iron deficiency makes a significant contribution to the recorded anemia situation among refugee women of childbearing ages. The predictors that influence the serum iron status of women in childbearing age in a refugee context include income generating activities, level of education, and estimated monthly income. Given the heavy reliance on plant-based foods which are poor sources of iron, dietary factors did not have influence on iron status of women in childbearing age in the context of the current study.

Recommendation

There is need to promote consumption of animal-based and iron-rich-food sources among women in childbearing age in Adjumani refugees' settlement to reduce the high reliance on starchy plant-based food sources and increase iron intake. The promotion program/interventions should also consider diversifying the economic activities of women in childbearing age in the refugee context. Future study should assess additional biomarkers, such as transferrin saturation or soluble transferrin receptor, alongside serum ferritin, to evaluate the exact contribution of iron deficiency to Anemia and should focus on conducting postprandial studies to assess actual bioavailability of iron in the body.

List of Abbreviations

OPM	Office of the Prime Minister
WCBA	Women of Childbearing Age
WHO	World Health Organization
MDI	Mean Daily Intake
MD	Mean Difference
MFSCI	Mean Ferritin Serum Concentration
Hb	Hemoglobin
UGX	Uganda Shillings
SPSS	Statistical Package for Social Scientists
PBS	Phosphate-buffered Saline
ELISA	Enzyme-linked Immunosorbent Assay
VHT	Village Health Team

Declarations

Ethics approval and consent to participate

The study followed the ethical research standards such as free & informed consent, privacy & confidentiality, ethical approval, and risks & benefits of conducting research, in accordance with the Declaration of Helsinki [75]. Ethical clearance was obtained from Gulu University Ethical Committee under GUREC-2023-552. Permission to conduct the study in the refugee settlement was also sought from the Office of the Prime Minister (OPM), community leaders and the participants. An informed consent form was used to seek consent from the study participants. Furthermore, the study participants were fully informed about the study's objectives, procedures, potential risks, and benefits before providing their consent. Blood sample was collected from the study participants in accordance with the Declaration of Helsinki standard [75]. In this study, clinical trial number was not applicable. Also, the final version of this manuscript has been read and approved by all listed co-authors.

Consent for Publication

Not Applicable.

Availability of data and materials

The data will be made available from corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CI contributed to the study through conceptualization, data curation, formal analysis, investigation, methodology, validation, writing of the original draft, and writing for review and editing. GK contributed to the study through drafting and writing of the original manuscript draft and writing for review and editing. GW was involved in conceptualization, formal analysis, methodology, supervision, validation, and writing for review and editing. RW contributed to the study through conceptualization, data curation, formal analysis, investigation, methodology, validation, writing of the original draft, and writing for review and editing. SO participated in conceptualization, formal analysis, methodology, supervision, validation, and writing for review and editing.

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Authors' information

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