Heliyonxxx (xxxx) xxx

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Iron-focussed nutritional status of mothers with children (6–59 months) in rural northern Ghana

Brenda Ariba Zarhari Abu[a,b], Jacques Eugene Raubenheimer[c,d], Violet Louise van den Berg[a,*]

[a] Department of Nutrition and Dietetics (G24), Faculty of Health Sciences, University of the Free State, 205 Nelson Mandela Drive, Bloemfontein, 9300, South Africa
[b] Wegmans School of Health and Nutrition, College of Health Sciences and Technology, Rochester Institute of Technology, 180 Lomb Memorial Drive, CIMS 78-A624, Rochester, New York 14623, USA
[c] Department of Biostatistics, School of Clinical Medicine, Faculty of Health Sciences University of the Free State, Bloemfontein, South Africa
[d] The University of Sydney School of Medicine, Pharmacology Faculty of Medicine and Health, University of Sydney, Room 308B, K06 1-3 Ross str, NSW, 2006, Australia

ARTICLE INFO

Keywords:
Health sciences
Public health
Hematological system
Women's health
Anthropology
Nutrition
Subsistence farming
Anaemia
Food fortification
Micronutrient intake
Women

ABSTRACT

Background: Anaemia, especially iron deficiency anemia, is an important cause of morbidity and mortality in African women and children.
Aim: To assess the intake of nutrients related to iron and anaemia status among mothers in smallholder agrarian communities in Northern Ghana where anaemia is known to be endemic.
Setting: Tolon Kumbumgu district and Tamale Metropolis in Ghana.
Methods: A cross-sectional study was conducted among 161 mothers with children 6–59 months. Questionnaires on socio-demographics, household food security and production and food frequencies, and three 24-hour recalls were administered during structured interviews, and BMI was assessed. Dietary intakes were analysed with the Ghana Nutrient Database® (version 6.02). Nutrient intake was evaluated using the estimated average requirements and iron intakes using the probability method.
Results: Most mothers (91.9%) had low literacy and were subsistence farmers. The staple diet was homemade unrefined, unfortified maize meal, homemade unfortified oil (shea butter), and seasonal green leafy vegetables (mostly amaranth), butternut, tomatoes, onions and legumes. Inadequate intakes of vitamin A (in 9.9%), folate (in 46.6%) and vitamin B_{12} (in 98.8%) were observed, in combination with high fibre (47.8 ± 19.0 g/day) intakes and high tea consumption. If 10% iron bio-availability was assumed, 33.1% were estimated to have inadequate iron intake; if 5% iron bio-availability was assumed, 80.8% were estimated to have inadequate iron intakes.
Conclusion: In these low socio-economic agrarian communities, mothers of infants are living on home produce and rarely consumed foods (fortified salt, cooking oil and wheat flour) from the national food fortification programmes intended to address anaemia and other micronutrient deficiencies.

1. Introduction

Anaemia is an important global risk factor for the health of women associated with increased risk of maternal and perinatal mortality, as well as adverse effects on cognitive and motor development, reduced physical stamina and low work productivity [1, 2]. A systematic review of 257 population-representative data sources from 107 countries worldwide for 1995–2011 reported that anaemia affected 38% of pregnant and 29% of non-pregnant women 15–49 years in 2011 [1]. The burden of anaemia falls particularly heavily on developing countries, and in Central and Western Africa, anaemia affected 56% of pregnant women and 47% of non-pregnant women of childbearing age, in 2011 [1].

Globally, the top-ranked cause of anaemia, contributing to up to 50% of all cases [3], is the inadequate intake of bioavailable iron [4], particularly in times of increased requirements, such as pregnancy and early childhood development, leading to iron deficiency (ID) and eventual iron deficiency anaemia (IDA). Other nutrient deficiencies, such as in vitamin A, folic acid, and vitamin B12 also directly or indirectly contribute to anaemia [5, 6]. Anaemia and IDA leads to persistent weakness, fatigue, and impaired immune system among affected women, and impaired physical and cognitive development among affected

* Corresponding author.
E-mail address: vdbergvl@ufs.ac.za (V. Louise van den Berg).

https://doi.org/10.1016/j.heliyon.2020.e04017
Received 14 May 2019; Received in revised form 1 March 2020; Accepted 11 May 2020

children [7]. The 2017 *Ghana Micronutrient Survey* reported the national prevalence of IDA at 8.9%, ID at 13.7%, vitamin A deficiency at 1.5%, folate deficiency at 53.8%, and vitamin B12 deficiency at 6.9%. To address the anaemia epidemic, the Ghana Health Service, with the support of the USAID/MOST project and in collaboration with stakeholders, in 2003, developed an Integrated Anaemia Control Strategy. This strategy targeted pregnant women, preschool and school-aged children with food-based interventions, as well as interventions to control malaria and helminth infection [5]. National food fortification in Ghana was launched in 2007 and the goal was to fortify wheat flour with vitamin A and B, iron and folic acid, and vegetable oils with vitamin A [8, 9] at the national level.

In the Northern Region of Ghana, the prevalence of anaemia was still 47.5% amongst women of childbearing age according to the Ghana Demographic and Health Survey 2014 [10]. This constitutes a drop of 20% in this group since 2008, compared to the Western and Upper West Regions where drops of 40% and 47% where realised. In the Eastern, Ashanti and Brong Ahafo Regions, anemia prevalence drops of 33%, 32% and 37% were recorded respectively [5]. In Ghana, the 2016 *Landscape Analysis of Anaemia and Anaemia Programming* reported 42% prevalence of anaemia amongst women at the national level [2]. Exploring the reasons for the persistently high levels of anaemia in these areas is thus important, particularly among vulnerable groups of women and children on smallholdings in the area, who live on subsistence farming.

The Northern Region is much drier than southern areas of Ghana, and has many more rural and sparsely populated communities who are involved in agrarian activities. This study formed part of a more extensive intervention [11, 12] in which data on the nutritional status, household food security, anaemia-related knowledge, attitudes and practices and preventative measures [13], as well as pica practices [14], were collected among mothers and their children between 6 and 59 months in agrarian communities in Northern Ghana, where anaemia is known to be endemic [5, 15]. This paper shares the baseline results regarding the iron-focussed nutritional status of these mothers.

2. Research methods and design

2.1. Study design and setting

A cross-sectional quantitative baseline study was conducted in April 2012 at the start of the wet season, in the Northern Region of Ghana.

2.2. Study population and sampling strategy

Tolon-Kumbumgu district and Tamale metropolis were randomly selected from a list of the 20 districts that constitute the Northern Region. Because the overall study had an intervention component, a community with a high prevalence of anaemia was purposively selected in each district using 2011 health records from Ghana Health Service; these were Gbullung from the Tolon-Kunbungu district and Tugu & Tugu-Yepala from the Tamale Metropolis. All mothers who had lived in the selected communities for at least 12 months, who were not pregnant, and had children aged 6–59 months old, were invited to participate in the study. The response rated at the baseline data collection is estimated at 95% since mother were willing to participate. The final sample included 161 mothers; 81 from Gbullung in the Tolon-Kumbumgu district and 80 from Tugu in the Tamale metropolis.

2.3. Data collection

All standard methods and published procedures for the relevant data collection were accurately followed to ensure reliability. Four research assistants, who all had health and nutrition professional backgrounds, were trained to improve their skills on estimation of serving sizes of food and non-biased probing of participants to ensure accurate questionnaire data collection. The researchers developed a set of questionnaires, based on an in-depth survey of the literature on ID, to assess the socio-demographics, food production practices, food security level, dietary intakes and usual eating patterns related to ID and anaemia; as well as other known dietary risk factors for ID. The questionnaires were administered during structured interviews conducted with the mothers in their homes. Since most mothers were not formally educated, questions were read to the participants in Dagbani and their responses were then written by the interviewer on the questionnaires in English. To ensure understanding of the local situation and to contextualise the findings, the primary researcher also observed the local customs and recorded these in a field journal.

The questionnaire used to assess food security was adapted and modified for the Assuring Health for All (AHA) Free State Study (performed among Black South Africans) from the 15-country Prospective Urban Rural Epidemiology (PURE) Study [16]. This questionnaire incorporated the validated 8-item Community Childhood Hunger Identification Project (CCHIP) Household Hunger Scale [17], as well as questions to assess household income, money spent on food, mechanisms adopted by families to cope with food shortages, and food production. Questions regarding dietary factors that are known to affect the bioavailability of iron, were compiled based on an in-depth literature review and included in the questionnaire.

The primary researcher and two trained field workers measured the women's heights and weights, observing all standard protocols [18].

A 75-item Food Frequency Questionnaire (FFQ) to assess the dietary patterns of the women, was developed based on the FAO Dietary Diversity Questionnaire [19] and adapted to reflect foods commonly consumed in this population. The reference period of the recall was three months before the interview. A chart with coloured pictures of all the listed foods was used as a guide for the FFQ recall. 24Hr-recalls for three non-consecutive days were included in the questionnaire to assess dietary intakes, and were administered according to a multiple-pass interview approach [20] in which mothers were facilitated to give an account for all foods eaten, the amount consumed, and the mode of preparation of the foods. Calibrated food models, as well as utensils, cups and dishes from the households, were used to help mothers describe portion sizes of foods eaten [21]. In the case of foods purchased from outside, the monetary values were asked to assist the accurate estimation of the amounts consumed. Interviews were conducted in the privacy of each woman's own home to improve truthful and accurate data collection. The participants were also assured that the data collected would be kept confidential.

2.4. Data analysis

Data were analysed using SAS/STAT software (Version 9.3 of the SAS system for Windows; Copyright © 2010 SAS Institute Inc.). Socio-demographic, household food production, and food security, anthropometry and dietary patterns and intakes were summarised as frequencies and percentages for categorical data and medians, means and standard deviations (SD) for continuous data. Height (metres) and weight (kilogrammes) were used to calculate the BMI and categorized as normal, underweight, overweight and obese [22]. The intakes of energy, macronutrients and the micronutrients relevant to anaemia, namely vitamins C, A, B12, folate and iron, were calculated from the three 24-hour recalls using the Ghana Nutrient Database (Version 6.02); and the averages of the three days' intakes were calculated with Microsoft Office Excel to express the final absolute intake values. The age-specific estimated average requirements (EAR) cut-points were used to evaluate the adequacy of intakes of all the nutrients (except iron) and EER according to the FAO/WHO (2004) vitamin and mineral requirements in human nutrition [21].

For iron, the probability method was used to assess the adequacy of iron intake at 5% and 10% bioavailability. Heme and non-heme iron have different but generally low bioavailability of iron after food intake, thus the probability method is recommend [21, 22, 23, 24]. Food security was scored and classified according to the CCHIP index [17], by which a final total score of zero indicates that a household is food secure; a score of one to four indicates that the household is at risk of hunger, and a score above four indicates that the household is going hungry.

2.5. Ethical considerations

The study was approved by the Ethics Committee of the Faculty of Health Sciences, University of the Free State in South Africa (ECUFS NR 24/2012) and the Noguchi Memorial Institute of Medical Research (NMIMR) in Ghana (NMIMR-IRB CPN 064/11–12). The Regional Health Director, as well as the traditional leaders in each community, granted permission for the study. All rights of the participants were observed according to the Helsinki declaration on ethics in handling research participants. Mothers who volunteered signed or thumb-printed informed consent forms after the study procedures were explained to them.

3. Results

The final sample constituted 161 mothers, each representing a household; 81 from Gbullung in the Tolon-Kumbumgu district and 80 from Tugu in the Tamale metropolis. For baseline measurements, it was hoped that the respondents from the two villages would be reasonably similar. Non-significant t-tests for independent samples on main outcome measurements (not shown) confirmed that the two groups were homogenous, and the baseline results of this article are thus presented for the entire sample as a whole.

3.1. Socio-demographic characteristics household food production

Table 1 summarises the socio-demographic characteristics of the mothers. Their mean age was 33.0, SD: ± 8.3 years. Most were married (97.5%), from the Dagomba ethnic group (96.3%) and practised the Muslim religion (98.1%). Most of the mothers (91.9%) had no formal education, and none were formally employed. All were engaged in subsistence farming, spending an average of 6.1 h per day at work; 84.5% reported earning a living through petty trading and sale of food crop production or livestock, while the rest (15.5%) reported that they were unemployed. Mothers reported spending a mean of GHS10.5 (≈USD5) per week on food. Although most households had electricity, 60% drew water from rivers, ponds and wells, for lack of piped water to their households.

Table 2 summarises the household food production. Almost all households grew vegetables, mostly green leafy vegetables, peanuts and other legumes, as well as seasonal vegetables, including tomatoes, onions and green peppers; cultivated cereal crops, mostly maize, sorghum, and rice; and owned livestock, mostly sheep and goats, and some cattle. Almost 60% cultivated beans (legumes) and 90% cultivated peanuts. About 40% grew fruit trees or had access to fruit trees. Most households (57.0%) produced food only for their consumption; 39.0% sold less than 50% of the food they produced and 4.0% sold more than 50%.

3.2. Household food security

Overall 50.5% of households were food insecure (43.8% at risk for hunger, 6.9% hungry) (Table 3). When mothers were asked to define ‘eating enough,’ most (54.8%) said that, for them, it meant ‘enough food for everyone until the next harvest season’. However, 15.9% also defined ‘eating enough’ as eating to ‘fullness’ or to ‘fill the stomach’. Overall, 79 (49.4%) of households reported having experienced periods of food shortages lasting a mean of 11.5 ± 6.7 weeks. About a quarter (25.3%) of these households reported shortages lasting more than 12 weeks at a stretch. In the periods of food shortages, most households (49.4%) reported that they found other food sources and 21.5% that they bought food from the market, 6.3% had sold assets, 5.1% had worked for payment in food, and 12.7% had borrowed money or food. Most mothers (79.9%) reported that staples lasted until the next harvest season, but only 43.1% indicated that vegetables lasted and 13.2% that fruits lasted until the next harvest.

3.3. Anthropometry

The mean BMI was 20.8 ± 3.72. As summarised in Table 4, 10% were underweight, and 11.3% were overweight or obese (class 1).

3.4. Dietary patterns

The responses of the mothers to the FFQ, are summarised in Table 5. The daily staple was maize porridge (88.1%) made from cooked, fermented maize meal and tuo-zaafi (TZ) (96.2%) made from cassava flour. Other cereals and starches that were consumed with high frequency (daily or 3–4 times per week), were tubers (mostly yams, when in season), *O'Henry* and *murasaki* sweet potatoes and corn on the cob. Whereas only 11.4% of the mothers reported consuming white bread daily, about half consumed it 1–4 times per week.

Table 1. Socio-demography (N = 161).

VARIABLE	n (%)/Mean ± SD
Age (years)	
≤19	2 (1.2)
20–29	38 (23.6)
30–39	70 (43.5)
40–49	28 (17.4)
>50	6 (3.7)
Did not know	17 (10.6)
Mean ± SD	33.0 ± 8.3
Highest level of education	
None	148 (91.9)
Primary (1–6 yrs)	10 (6.2)
JSS level (7–10 yrs)[#]	2 (1.2)
SSS/Vocational school (11–14 yrs)[#]	1 (0.6)
Religion	
Christian	3 (1.9)
Muslim	158 (98.1)
Ethnicity	
Dagomba	155 (96.3)
Moshi	1 (0.6)
Hausa	1 (0.6)
Fulani	3 (1.9)
Ewe	1 (0.6)
Employment status	
Self employed	136 (84.5)
Unemployment	25 (15.5)
Marital status	
Married	157 (97.5)
Single	3 (1.9)
Cohabiting	1 (0.6)
Household has electricity	
Yes	122 (79.2)
No	32 (20.8)
Household water supply	
Fetches piped water at public standpipes	59 (36.9)
Fetches water from a borehole	5 (3.1)
Fetches water from a well	3 (1.9)
Draws water from a river/pond	93 (58.1)

[#] JSS = junior secondary school, SSS = senior secondary school.

Table 2. Household food production (N = 161).

Variable	n (%)
Households that grew vegetables	154 (95.6)
Types of vegetables grown	
Cabbage	1 (0.6)
Carrot	71 (44.1)
Green leafy vegetables (mostly bitor/bra, amaranth)	103 (71.5)
Pumpkin/butternut	97 (67.4)
Beans (legumes)	83 (57.6)
Peanuts (groundnuts)	145 (90.1)
Others (okra, pepper, tomatoes)	126 (78.3)
Household that cultivated crops	160 (99.4)
Types of crops cultivated	
Maize	159 (98.8)
Rice	155 (96.3)
Sorghum	121 (75.2)
O'Henry or Murasaki sweet potatoes	80 (49.7)
Cassava	129 (80.1)
Cowpea	1 (0.6)
Millet	1 (0.6)
Household that grew/had access to fruit trees (n=159)	62 (39.0)
Types of fruits (n=105)	
Mango	49 (46.6)
Cashew	20 (19.0)
Guava	5 (4.8)
Baobab	19 (18.1)
Others (banana, pawpaw, moringa, shea nut)	12 (11.4)
Household that owned livestock (n=159)	140 (88.0)
Beef Cattle (n=29)	(Mean number[a] ± SD: 5.9 ± 8.9)
Unknown number	9 (31.0)
1-10	16 (57.1)
11-20	2 (7.1)
31-40	1 (3.6)
Dairy Cattle (n=17)	(Mean number[a] ± SD:3.4 ± 6.3)
Unknown number	9 (52.9)
1-5	6 (35.3)
6-10	1 (5.9)
20-25	1 (5.9)
Sheep (n=102)	(Mean number[a] ± SD:6.3 ± 11.0)
Unknown number	29 (28.4)
1-10	60 (58.8)
11-20	11 (10.8)
21-30	1 (1.0)
91-100	1 (1.0)
Goats (n=112)	(Mean number[a] ± SD: 4.6 ± 4.7)
Unknown number	29 (25.9)
1-10	75 (67.0)
11-20	8 (7.1)
Chicken (n=99)	Mean number[a] ± SD: 6.8 ± 8.9
Unknown number	37 (37.4)
1-10	44 (44.4)
11-20	13 (13.1)
21-30	4 (4.1)
41-50	1 (1.0)

[a] Calculated from those with a known number of animals.

Overall 95.8% of the mothers consumed butternut at least four times per week (61.3% daily), when in season. Other vitamin A-rich vegetables, such as pumpkin, carrots, and sweet potato, were rarely consumed. Most mothers (72.0%) consumed amaranth leaves at least twice a week. Other dark green leaves consumed weekly, were bean leaves, baobab leaves, bra (*Hibiscus sabdariffa*) leaves and cassava leaves; all of which are seasonal and not available throughout the year (at the time of the interviews, these vegetables were in season). More than 90% of the mothers consumed tomatoes and onions 3–7 times per week (mostly in soups or sauces); 50.3% consumed green/sweet peppers daily, and 70% consumed eggplant at least once per week. Most mothers consumed mangoes, oranges and wild berries daily or weekly. Juice intake was low, and wild fruits, such as shea nuts, were only eaten when in season.

Almost nobody reported daily consumption of meat, except for dried anchovies which, in 96.2% of households, were pounded into a powder and incorporated as a condiment into food daily (but the actual amount of fish consumed per person in a household was negligible). Most (around 80%) only occasionally consumed organ meat such as liver, kidney, and heart. About a third (35.9%) ate blood-based foods (referring to blood collected when animals are slaughtered, the blood is then cooked and eaten by itself, or with other foods) occasionally, whereas the rest reported never eating it. Most mothers (96.2%) never ate pork. Beef and goat was the most commonly consumed red meats; eaten 1–4 times per week by 35.3% and 40.8%, respectively. Overall less than 20% reported that they consumed lamb (19.7%), chicken (14.2%), and worms (18.9%), 1–4 times per week. Eggs were consumed 1–4 times per week by 21.7%, whereas most (68.2%) reported consuming eggs only occasionally. Legumes, nuts, and seeds were mostly used in the whole, unprocessed form. More than 90% consumed dried beans and cowpea 1–4 times weekly. About a quarter of mothers reported eating peanuts (raw, roasted, or in a soup) daily, and another quarter, 3–4 times per week.

Most mothers rarely consumed dairy products, mainly as cow's milk (81.0% occasionally) and yoghurt (70.7% occasionally).

The primary source of fat consumed was homemade shea butter (a semi-solid oil), which is mostly used for cooking. Overall 42.6% of mothers consumed shea butter daily, and 57.4% consumed it 3–4 times per week.

The majority (68.6%) reported adding granular sugar to their tea and their breakfast porridge daily, with another 19.6% doing so 3–4 times per week. Most mothers never drank coffee or green tea, but 15.7% drank black tea daily, and 55.4% drank it 3–4 times per week. Almost half of the mothers drank Milo (mixed in with water) at least once per week (21.4% daily, 4% 3–4 times per week, and 28% once a week). Most mothers (94%) only consumed soft drinks (mainly carbonated) occasionally. Only one mother reported using any alcohol. Most (94.3%) used dawadawa fruit (African locust), a seasonal wild fruit that is dried and processed into a powder. The remainent African locust seeds are then fermented and used as a daily condiment (also called dawadawa).

3.5. Adequacy of nutrient intakes

The mean daily intakes of energy, macronutrients, and micronutrients relevant to anaemia, estimated from the average of three 24hr-recalls for non-consecutive days are summarised in Table 6. Energy intakes were high, with a mean of around 13 000 kJ per day; only two mothers had inadequate energy intakes (kJ/kg/d). Mean protein (72 g/day; 1224 kJ), carbohydrate (492 g/day; 8364 kJ) and fat intakes (104.8 g/day; 3982 kJ) constituted 9.3%, 63.9% and 30.4% of mean total daily energy intake. The entire sample had adequate intakes of carbohydrate, and protein. The mean fibre intake was high, at 47.8 ± 19.0 g/day.

If it was assumed that 10% of the iron in the diet of these mothers was bioavailable [20], 33.1% of the mothers were estimated to have inadequate iron intake. If 5% bioavailability of iron in the diet was assumed, an estimated 80.8% of the mothers were estimated to have inadequate iron intakes [20]. Regarding the vitamins that are relevant to iron status and anaemia, 9.9%, 94.4% and 46.6% had inadequate intakes of vitamins A,

Table 3. Household food security (N = 161).

HOUSEHOLD FOOD SECURITY CLASSIFICATION	n (%)
Food secure	79 (49.4)
At risk of hunger	70 (43.8)
Experiencing hunger	11 (6.9)
MOTHERS' DEFINITION OF 'EATING ENOUGH FOOD' (n=157)	
'Enough money to buy all needs'	17 (10.8)
'Ability to save some money'	1 (0.6)
'When there is enough food for everyone'	14 (8.9)
'Enough food for everyone until the next harvest season'	80 (54.8)
'To be satisfied (to fill the stomach)'	25 (15.9)
'When children in the house do not cry of hunger'	1 (0.6)
'I do not know'	13 (8.3)
HOUSEHOLD COPING STRATEGY DURING PERIOD OF FOOD SHORTAGE	
Has the household ever experienced periods of food shortage (n=160)	79 (49.4)
If yes, state the total number of weeks the household had food shortage over the last 12 months: (n=79)	
1–12 weeks	59 (74.7)
13–24 weeks	18 (22.8)
25–36 weeks	2 (2.5)
Mean ± SD	11.5 ± 6.7
How did the household cope during these times of food insecurity?	
Found other sources (n = 79)	39 (49.4)
Asked family/relatives/neighbours for help (money/food) (n = 79)	1 (1.3)
Sold assets (n = 79)	5 (6.3)
Worked for payment in food (n = 79)	4 (5.1)
Borrowed money or food (n = 79)	10 (12.7)
Bought food to supplements farm produce (n = 79)	17 (21.5)

B12 and folate, respectively, whereas 12.4% had folate intakes above the UL. Almost all mothers (98.8%) had adequate vitamin C intakes.

4. Discussion

This study explored the anaemia-focussed dietary intakes of non-pregnant mothers of children 6–12 months in the Northern Region of Ghana, where endemic anaemia persists amongst women despite national efforts to address the problem [5, 10]. The results showed that most participants in this setting had little to no formal schooling, lived in mud huts, cooked on open fires and drew water from ponds and wells. They made a living almost solely through subsistence farming and experienced high levels of food insecurity. Moreover, the study found that these households lived almost entirely off their own and local produce, thus totally forfeiting the benefits of the national food fortification programme [48,49].

Northern Ghana experiences a rainy season from April to mid-October, followed by a dry season from November to March. About half of households in the study had experienced food insecurity in the 12 months before data collection, which was higher than the rate of 27% food insecurity previously reported for the Northern Regions [26]. Similar to a previous report for this area [27], about half of the households (represented by the mothers) interviewed, reported food shortages lasting about three months per year. Thus, they were not able to produce enough and store enough farm produce for home consumption throughout the year. During times of food shortages, households mostly coped by buying the foods that they otherwise produced from the local marketplace [27]. Proposed strategies to address food shortages amongst smallholder farmers in the dry season in Northern Ghana, include programmes to raise environmental consciousness to curb poor land and water management, as well as interventions to improve food production, food access and physical infrastructure in the area, including roads and irrigation dams [28, 29].

The lack of piped water to most households so that 60% were dependent on water drawn from rivers, ponds and wells, necessitates intervention, as infections from unsafe water may cause ID and IDA. The mechanism is understood to be related to the fact that the body down-regulates iron absorption to fend off infection [30].

Overall energy intakes among these mothers were quite high, combined with high intakes of carbohydrates and fat, and was attributable to large portions of the staple foods that the women were observed to consume, in addition to daily consumption of shea butter. Their mean BMI was, however, in the lower range of normal weight (similar to the findings of the 2014 Ghana Health and Demographic Survey [10]) probably due to high levels of activity, as these women reported spending a mean of around six hours per day working the land, in addition to manual household chores like processing flour and extracting shea oil [18, 31].

As maize was available all year round, homemade maize flour, produced in the households in small quantities according to their needs, was the staple used in tuo-zaafi (a pap made from cooked maize dough/flour, a small amount of dried cassava dough, and water without salt and eaten with a variety of soups) and other highly consumed dishes. Only 10.5%, however, reported daily consumption of bread made from commercially available fortified wheat flour [9]. Although most households in the current study consumed shea nut oil daily, it was mostly homemade (using an indegenous process that is illustrated by Peace Corps Ghana [32]). Fortified vegetable oil was commercially available in the communities, but was expensive. Although fortification programmes have helped improve the nutritional status of vulnerable communities in many parts of the world [33, 34], these rural communities were not benefitting from the national fortification program. Maize flour fortification at the factory level is feasible and effective in sub-Saharan countries like South Africa [35], but may not be applicable in smallholder agrarian communities like these in northern Ghana. Venkatesh Mannar [36] suggested that in farming communities, the best approach might be micro-fortification coupled with nutrition education. Home fortification in pilot stages in selected districts seemed feasible. However this approach also poses some challenges, including the need to mill maize in bulk, and large fortificant packages. Thus, if a mother runs out of flour

Table 4. Anthropometry (N = 161).

Variable categories		n (%)
Underweight	<18.5 kg/m^2	16 (10.0)
Normal	18.5–24.9 kg/m^2	125 (78.6)
Overweight	25.0–29.9 kg/m^2	14 (8.8)
Obese class I	30.0–34.9 kg/m^2	4 (2.5)
Obese class II	35.0–39.9 kg/m^2	0 (0.0)
Obese class III	≥40.0 kg/m^2	0 (0.0)

and needs to prepare some for cooking as a matter of urgency, she may not have access to fortificant in small quantities to do so. Another challenge is that donor-dependent supply of fortificants to these communities may not be sustainable.

Although a high percentage of the households reared animals, bioavailable haem iron sources were not consumed daily. Animals were rarely kept for household consumption, but rather represented a form of wealth index, used as collateral for borrowing money against, or as an emergency 'fund to sell when having to pay hospital bills, funeral rites, or to buy foods in times of food shortage'. Fish intake was low because fish is rarely available in areas not close to the sea, rivers or streams. 'Keta school boys' and anchovies, imported from Southern Ghana, were available in the local market but were expensive due to the transportation costs involved. Therefore, dried anchovies were used more as a condiment, added as small quantities of dried powder to flavour the staple soups. Although these amounts were insignificant as a source of protein and iron, a benefit it may have contributed was adding at least some MFP (meat, fish and poultry) factor to enhance absorption of non-haem iron from the rest of the diet [28].

On the other hand, though, studies found that the effects of meat, and other enhancers, on iron absorption can be negated by the simultaneous consumption of food components that inhibit iron absorption [37]. In this study population, very high intakes of fibre and phytate from unprocessed cereals and legumes (dried beans and peas), and peanuts, which were the primary source of non-haem iron among these women, likely impacted negatively on the absorption of non-haem iron. The mean fibre intake was 47.8 ± 19.0 g/day, which is almost double the recommended level of intake for adults (26–29 g/day) [38]. Furthermore, most mothers also consumed tea daily with meals. In populations with marginal iron status, a negative association exists between tea consumption and iron status [39]. Assuming 5% or 10% bioavailability of iron in the

Table 5. Dietary patterns of the mothers based on the foods reported in the FFQ (N = 161).

Foods	FFQ						
	Daily	3–4x/week	1x/Weekly	2–3x/month	Monthly	Occasionally	Never
	%	%	%	%	%	%	%
Cereals, grains and starches							
Maize porridge	88.1	5.0	2.5	0.6	0.0	3.1	0.6
Sour porridge	17.1	11.4	13.3	0.6	0.0	53.8	3.8
Millet porridge	35.4	9.5	3.2	0.0	0.0	9.5	42.4
*Tuo-zaafi (TZ)/Banku	96.3	3.1	0.0	0.0	0.0	0.6	0.0
White Bread	11.4	28.5	19.0	3.2	0.0	38.0	0.0
Pasta	3.2	10.8	14.6	7.0	0.0	63.3	1.3
O'Henry or Murasaki sweet potatoes	19.0	58.2	12.7	5.1	0.0	5.1	0.0
Rice	2.5	77.9	15.2	1.3	0.0	3.2	0.0
Corn on cob	25.3	53.1	18.4	0.0	0.0	3.2	0.0
Tubers	53.2	32.9	8.2	0.6	0.0	5.1	0.0
Yellow vegetables (vitamin A sources)							
Butternut	61.3	34.5	0.7	0.0	0.0	0.0	3.2
Pumpkin	0.6	1.9	0.0	0.0	0.0	0.6	96.9
Carrot	0.6	1.9	0.6	0.6	0.6	37.3	58.9
Sweet potato	0.0	53.2	0.0	0.0	0.6	0.0	0.0
Dark green leafy vegetables							
Amaranth leaves	7.0	72.0	19.1	0.6	0.0	1.3	0.0
Cassava leaves	1.3	28.5	50.6	5.7	0.6	12.7	0.6
"Spinach"/Nkontomire (cocoyam leaves)	0.0	4.4	6.3	2.5	0.0	64.6	22.2
Bean leaves	0.6	54.4	27.9	4.4	0.0	10.1	2.5
Pumpkin leaves	0.6	0.0	0.6	0.0	0.0	0.0	98.7
Mellon leaves	0.6	0.6	0.6	0.0	0.0	0.0	98.1
Bitor/Bra leaves (*Hibiscus sabdariffa*)	0.6	36.1	20.9	12.7	0.6	24.7	4.4
Wild leafy vegetables (e.g. baobab leaves)	0.0	54.1	21.0	5.1	0.0	3.2	16.6
Other vegetables							
Green/sweet pepper	50.3	0.0	0.0	0.0	0.0	0.0	30.2
Tomatoes	53.2	44.9	0.6	0.0	0.0	1.3	0.0
Onions	98.1	1.3	0.6	0.0	0.0	0.0	0.0
Egg plant	1.9	54.1	15.9	3.2	0.0	22.3	2.6
Yellow/orange fruit (vit A sources)							
Mango	45.2	29.9	17.8	3.2	0.0	3.8	0.0
Papaya	1.3	6.4	7.6	8.9	0.0	72.0	3.8
100% apricot/cantaloupe juice	2.6	0.0	0.6	1.3	0.0	22.6	72.9

(*continued on next page*)

Table 5 (*continued*)

Foods	FFQ						
	Daily	3–4x/week	1x/Weekly	2–3x/month	Monthly	Occasionally	Never
	%	%	%	%	%	%	%
Other fruits and juice (vit C sources)	0.0	47.1	0.0	0.0	0.6	0.0	0.0
Orange	1.3	48.4	22.3	3.8	0.0	23.6	0.6
Orange juice	1.3	0.6	0.0	0.0	0.6	73.3	24.8
Berries	0.0	70.0	12.1	4.5	0.0	6.4	3.8
Vitamin C fortified juice	0.0	0.0	1.3	0.0	0.0	72.4	26.3
Other fruits/wild fruits/100% juices	0.6	0.0	3.7	1.9	0.0	67.1	21.1
Meat (heme sources)							
Organ meat							
Liver	0.0	7.1	7.7	6.4	0.6	78.2	0.0
Kidney	0.0	5.1	3.8	1.3	1.3	81.5	2.6
Heart	0.0	2.6	2.6	3.8	0.6	81.5	8.9
Blood-based food	0.0	0.0	0.6	0.0	0.0	35.9	63.5
Flesh meat							
Beef	0.0	15.4	19.9	10.3	0.0	51.9	2.6
Pork	0.0	0.6	0.0	0.0	0.0	3.2	96.2
Lamb	0.0	10.8	8.9	8.9	0.0	70.1	1.3
Goat	0.0	7.0	5.1	5.1	0.6	81.5	0.6
Game	1.9	25.5	15.3	3.2	0.0	54.1	0.0
Chicken	0.0	10.3	3.9	3.9	0.0	78.2	2.6
Duck	0.6	1.9	3.9	0.6	0.0	69.2	23.7
Edible worms (e.g. shea tree worms (taantunna)	0.7	18.9	0.0	3.3	0.0	59.5	5.2
Fish and other seafood							
Anchovies	96.2	0.0	1.9	0.0	0.0	1.9	0.0
Eggs	0.6	9.6	12.1	9.6	0.0	68.2	0.0
Legumes, nuts and seeds							
Dry beans	1.3	50.0	42.3	1.9	0.0	4.5	0.0
Dry peas	3.2	50.6	43.0	0.6	0.0	0.0	0.6
Peanuts/Tree nuts (eaten raw, boiled or used in soup)	68.8	26.6	3.3	0.0	0.0	1.3	68.8
Melon seeds (wild melon or egushi)	0.6	1.3	0.0	0.0	0.0	3.9	94.2
Milk and milk products							
Cow's milk	1.9	1.9	5.7	3.2	0.6	81.0	5.7
Yoghurt	0.0	0.6	1.9	0.6	0.0	70.7	26.1
Goat's milk	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Fats & Oils							
Shea oil used for cooking	42.6	57.4	0.0	0.0	0.0	0.0	0.0
Sweets/Sugar							
Sweets/Sugar	68.6	19.6	2.6	0.0	0.0	9.6	0.6
Beverages, alcohol							
Coffee	0.6	2.5	1.3	0.6	0.0	27.9	67.1
Tea	15.7	55.4	9.4	1.9	0.0	17.0	0.6
Chocolate drink	0.6	1.3	0.0	0.0	0.6	3.7	93.8
Milo	21.4	5.0	28.0	14.3	0.0	42.4	4.3
Carbonated drinks	1.3	0.6	2.5	0.6	0.6	89.9	4.4
Alcohol	0.6	0.0	0.0	0.0	0.0	0.0	99.4
Locally brewed beer	0.0	0.6	0.0	0.0	0.0	0.0	99.4
Spices, condiments							
Soy products	0.0	7.0	7.0	1.3	0.0	48.7	36.1
[#]Dawadawa (condiment)	94.3	1.3	1.3	0.0	0.0	3.2	0.0

[*] Tz/Banku (pap made from cooked fermented maize dough and cassava dough).
[#] Dawadawa is made from fermented African locust beans or baobab seeds.

current study, as suggested by the FAO/WHO for communities in developing countries [21, 22], 80.8% or 33.1% of these women, respectively, likely had inadequate iron intakes despite a mean intake of about 20 mg/day from their diets [37].

In this community, legumes were cultivated and frequently consumed. Legumes are good sources of protein, and iron and some varieties have low levels of antinutritive factors [40, 41]. The combination of legumes and cereals like maize in a vegetarian diet provides the full profile of the essential amino acids [42]. Legume crops also increased indigenous nitrogen production, improves soil fertility, and reduce pest and disease problems when used in rotation with non-leguminous crops [43]. The use of legumes should, therefore, be encouraged in communities like these. Dawawada made from the African locust seed or beans is another commonly used fortied condiment. Fortified commercial

Table 6. Evaluation of mean nutrient intakes estimated from 3 × 24h-recalls (N = 161).

Variable	Mean intake ±SD	Inadequate Intake	Adequate Intake	Excessive Intake
		n (%)	n (%)	n (%)
Energy (kCal/day)	3116.7 ± 1163.3	2 (1.3)	158 (98.8)	
(kJ/day)	13 090 ± 4 886			
Macronutrients				
*Protein (g/day)	72.0 ± 38.2	0 (0.0)	143 (100.0)	0 (0.0)
Carbohydrate (g/day)	492 ± 190. 2	0 (0.0)	161 (100.0)	0 (0.0)
Fat (g/day)	104.8 ± 44.1	0 (0.0)	161 (100.0)	
Dietary fibre (g/day)	47.8 ± 19.0	0 (0.0)	161 (100.0)	
Vitamins				
Vitamin C (mg/day)	197.5 ± 66.8	0 (0.0)	161 (100.0)	0 (0.0)
Vitamin A (μg RAE/day)	771.4 ± 394.8	16 (9.9)	145 (90.1)	0 (0.0)
Vitamin B_{12} (μg)	0.7 ± 2.6	152 (94.4)	9 (5.6)	0 (0.0)
Folate (μg)	785.7 ± 662.5	75 (46.6)	66 (41.0)	20 (12.4)
Minerals				
Iron (mg)	20.4 ± 9.9			

Percentage of population which probably have inadequate intakes of iron if 5% bioavailability of iron is assumed: 80.8%.
Percentage of population which probably have inadequate intakes of iron if 10% bioavailability of iron is assumed: 33.1%.
Intakes of folate, vitamins A, B12, and C were evaluated against the estimated average requirement (EAR) and upper limit (UL) (WHO/FAO, 1988; 2002; 2004 guidelines). Adequacy of nutritional intake is determined by additional variables (e.g., age, weight, breastfeeding status, menstruation, etc.) over and above simply the units of intake.
* 18 Protein values are missing due to missing values for the mothers' breastfeeing status and/or mothers' age.

condimment such as boulon cubes have been shown to be source of iodine and micronutrient [49,50].

At the time of data collection, also the beginning of the rainy season, vitamin C and folate intakes estimated from 24h recalls were adequate for all, and vitamin A intake adequate for most participants. The FFQ indicated that fruit and vegetable intake was, however, mostly seasonal. The vegetation of the Northern Region does not allow for citrus fruits cultivation. About a fifth of households had access to baobab trees. The fruit of the baobab contains about ten times as much vitamin C as oranges [44]. Baobab fruits, berries and other wild fruits that are also good sources of vitamin C, are seasonal though. The communities do not have the means to preserve fruits (except for 'dawadawa', a wild fruit and excellent source of beta-carotene, a precursor for vitamin A, that they used indegenous knowledge to preserve) [45].

At the time of the interviews, most of the households were growing seasonal vegetable sources of vitamin C, beta-carotene (vitamin A) and folate. These included butternut and various green leafy vegetables, which are traditionally cooked and eaten as a relish together with the starchy staple food. During the dry season, intakes of these vegetables may be compromised, which is particularly troublesome to the 10% of mothers who had inadequate vitamin A intakes at the time of the study. The communities may, therefore, benefit from irrigation projects [28, 46], which may also improve the income and purchasing power of households.

Even though vitamin C is recognised as an enhancer of iron absorption, the majority of studies in young women in industrualised settings have not found any association between iron status and total daily vitamin C intake, or fruit and vegetable intakes [37]. Furthermore, a recent biochemical analysis of amaranth, baobab and hibiscus (consumed in this study population), found that these are good sources of iron, although they also contain oxalates, which inhibit iron bioavailability [47].

In this study population, almost 95% of this population had inadequate intakes of vitamin B12, as estimated from three 24h-recalls, which may be explained by their relatively infrequent intakes of foods from animal sources, including meat, dairy and eggs, which are the only dietary sources of this nutrient. About half (46.6%) of the mothers also had inadequate intake of folate. Though the FFQ indicated regular intakes of green leafy vegetables, which are good sources of folate, the quantities consumed may have been rather low. At the beginning of the rainy season, most vegetables become expensive to buy. Folate can also be lost during the harvest, preparation or storage of food. Folic acid, the synthetic form of folate, is used together with vitamin B12, to universally fortify wheat flour in Ghana, which this population did not commonly consume [24].

A limitation of this study was the lack of biochemical data on the blood levels of the micronutrients to correlate with the nutrient intake levels and iron status in the population. However, it is well-established that anaemia rates amongst the target population are very high in this area [5]; thus a high level of ID was very probable. Another restriction of the study, is the small sample size that may limit the extent to which the findings may be generalised to the study population.

5. Conclusions and recommendations

Despite subsistence farming, which should contribute to household food security, about half of this population of mothers of young children from agrarian smallholdings in Northern Ghana were found to be at risk of hunger. Periods of food insecurity, high intakes of fibre, phytates and tea (with meals and iron supplements), combined with almost absent intakes of fortified foods, low intakes of haem sources, and seasonality of vitamins C-rich and A-rich fruits and vegetables, may however, exacerbate ID in this study population, and explain the persistence [5] of high levels of anaemia. In mothers already disposed to ID through menstruation, pregnancy, and lactation, these risk factors may contribute to the high anaemia prevalence in the area [5]. As the primary caregivers in charge of food preparation in their households, their practices translate to the feeding practices of their young children, putting their young children at similar risk for ID and anaemia and related health consequences. Due to their mostly self-sufficient dietary practices, the mothers rarely consumed foods from the national fortification program, mainly iodine-forified salt, wheat flour (fortified with Vitamin A, B12, folic acid, niacin, thiamin, riboflavin, zinc and iron) or vegetable oils (fortified with vitamin A). Nutrition education on improving the iron bioavailability from their diets may, therefore, be a viable option in these communities, and possibly other similar communities in developing countries, to address the global public health issue of ID and anaemia. A successful food-based nutrition education approach to enhance iron and iron--related nutrients intake could reduce anaemia within the community, and decrease the need for more costly interventions like fortification and supplementation.

More research is needed in such agrarian communities on the bioavailability of iron from mixed diets, and how to harness the indigenous knowledge to manage ID. Insufficient production to sustain the food supply throughout the dry seasons was the primary cause of food insecurity in these communities. Lastly, innovative ways to reach these vulnerable communities through sustainable fortification and supplementation programmes should be investigated.

Declarations

Author contribution statement

B. Abu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

V. Van Den Berg: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

J. Raubenheimer: Analyzed and interpreted the data.

Funding Statement

B. Abu was supported by the Ghana Education Trust Fund.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors wish to express gratitude to all the research assistants, community volunteers and participants of the study, as well as the Northern Regional Health Directorate, and the Tamale Metropolitan and Talon-Kumbungu district health directorates.

References

[1] G.A. Stevens, M.M. Finucane, L.M. De-Regil, C.J. Paciorek, S.R. Flaxman, F. Branca, et al., Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data, Lancet Glob. Heal. 1 (1) (2013 Jul 1) e16–25 [Internet]. Elsevier [cited 2019 Apr 29] Available from: http://www.ncbi.nlm.nih.gov/pubmed/25103581.

[2] M.M. Rahman, S.K. Abe, M.S. Rahman, M. Kanda, S. Narita, V. Bilano, et al., Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: systematic review and meta-analysis1,2, Am. J. Clin. Nutr. 103 (2) (2016 Feb 1) 495–504 [Internet]. Narnia [cited 2019 Apr 30] Available from: https://academic.oup.com/ajcn/article/103/2/495/4662868.

[3] N. Petry, I. Olofin, R.F. Hurrell, E. Boy, J.P. Wirth, M. Moursi, et al., The proportion of anemia associated with iron deficiency in low, medium, and high Human Development Index countries: a systematic analysis of national surveys, Nutrients 8 (11) (2016), E693 [Internet] Available from: https://www.mdpi.com/2072-6643/8/11/693.

[4] N.J. Kassebaum, R. Jasrasaria, M. Naghavi, S.K. Wulf, N. Johns, R. Lozano, et al., A systematic analysis of global anemia burden from 1990 to 2010, Blood 123 (5) (2014) 615–624.

[5] SPRING Ghana Health Services, Ghana: Landscape Analysis of Anemia and Anemia Programming, 2016 [Internet]. Arlington, VA Available from: https://www.spring-nutrition.org/publications/reports/ghana-landscape-analysis-anemia-and-anemia-programming.

[6] D. Benoist, Conclusions of a WHO Technical Consultation on folate and vitamin B12 deficiencies, Food Nutr. Bull. 29 (2) (2008) S238–244.

[7] N.M. Abu-Ouf, M.M. Jan, The impact of maternal iron deficiency and iron deficiency anemia on child's health, Saudi Med. J. 36 (2) (2015) 146–149.

[8] University of Ghana, GroundWork, University of Wisconsin-Madison, KEMRI-Wellcome Trust, UNICEF, Ghana Micronutrient Survey, 2017 [Internet]. Accra, Ghana; Available from: http://groundworkhealth.org/wp-content/uploads/2018/06/UoG-GroundWork_2017-GHANA-MICRONUTRIENT-SURVEY_Final_180607.pdf.

[9] Global Allegions for Improved Nurition (GAIN), Ghana Launches a Food Fortification Program, 2007 [Internet] Available from: https://www.gainhealth.org/knowledge-centre/ghana-launches-national-food-fortification-program/.

[10] Ghana, Statistical Service (GSS), Ghana Health Service (GHS), ICF Internationa. Ghana Demographic and Health Survey. Demographic and Health Survey 2014. 2014, 2015. Rockville, Maryland, USA [Internet] Available from: https://dhsprogram.com/pubs/pdf/FR307/FR307.pdf.

[11] B.A. Abu, V. Louw, J. Raubenheimer, V. van den Berg, Incorporating adult learning principles in an intervention implementation: experiences from an iron deficiency (ID) education program in Ghana, in: Micronutrient Forum. Addis Ababa, Ethiopia, 2014 [Internet] Available from: https://micronutrientforum.org/wp-content/uploads/2014/12/0358.pdf.

[12] B. Abu, V. Louw, J. Raubenheimer, V. Van den Berg, Designing interventions for resource poor communities with low literacy: an example of an iron deficiency (ID) education program in Ghana, in: Micronutrient Forum. Addis Ababa, Ethiopia, 2013.

[13] B.A.Z. Abu, V.J. Louw, A. Dannhauser, J.E. Raubenheimer, V. van den Berg, Knowledge, attitudes and practices regarding iron deficiency among mothers in an anemia endemic population in Northern Region of Ghana, Matern. Child Nutr. 9 (Suppl 3) (2013) 1 [Internet] Available from:.

[14] B.A.Z. Abu, V.L. van den Berg, J.E. Raubenheimer, V.J. Louw, Pica practices among apparently healthy women and their young children in Ghana, Physiol. Behav. 177 (April) (2017) 297–304 [Internet]. Elsevier Available from:.

[15] Ghana Statistical Service, Noguchi Memorial Institute for Medical Research, ORC Macro. Ghana Demographic and Health Survey 2003, Calverton, Maryland, 2004.

[16] C.M. Walsh, F.C. Van Rooyen, C.M. Walsh, Household food security and hunger in rural and urban communities in the Free State Province, South Africa, Ecol. Food Nutr. 54 (2) (2017) 118–137 [Internet]. Routledge Available from:.

[17] 'CA Wehler, R.I. Scott, J.J. Anderson, The community childhood hunger identification project: a model of domestic hunger—demonstration project in Seattle, Washington, J. Educ. Behav. 24 (1) (1992) 29S–35S [Internet] Available from: https://www.jneb.org/article/S0022-3182(12)80135-X/abstract.

[18] R.S. Gibson, Principles of Nutritional Assessment, second ed., Oxford University Press, New York, 2005, p. 259.

[19] G. Kennedy, T. Ballard, D. M, Guidelines for Measuring Household and Individual Dietary Diversity, 2013 [Internet]. Rome, Italy Available from: http://www.fao.org/3/a-i1983e.pdf.

[20] R.D. Lee, D.C. Nieman, Nutritional Assessment, third ed., McGraw-Hill, Boston, 2013.

[21] R. Gibson, E. Ferguson, HarvestPlus Technical Monographs 8: an Interactive 24-hour Recall for Assessing the Adequacy of Iron and Zinc Intakes in Developing Countries, 2008. Washington DC.

[22] World Health Organization, Obesity: Preventing and Managing the Global Epidemic. World Health Organization - Technical Report Series 894, 2000. Geneva.

[23] L. Allen, B. de Benoist, D. Dary, R. Hurrell, Guidelines on Food Fortification with Micronutrients, 2006 [Internet] Available from: http://www.who.int/nutrition/publications/guide_food_fortification_micronutrients.pdf.

[24] Joint FAO/WHO Expert Consultation on Human Vitamin and Mineral Requirements, Vitamin and mineral Requirements in Human Nutrition, 2004 [Internet] Available from: https://apps.who.int/iris/bitstream/handle/10665/42716/9241546123.pdf?ua=1.

[26] L. Biederlack, J. Rivers, Comprehensive Food Security & Vulnerability Analysis Guidelines (CFSVA): Republic of Ghana, 2009 [Internet]. Rome, Italy Available from: https://reliefweb.int/sites/reliefweb.int/files/resources/C52F59544 6FC19B2852575B4005D0E17-Full_Report.pdf.

[27] FAO, Food security situation in northern Ghana, coping strategies and related constraints, J. Agric. Res. 3 (5) (2008) 334–342.

[28] M. Steiner-Asiedu, B. Abu, J. Setorglo, D.K. Asiedu, A.K. Anderson, The impact of irrigation on the nutritional status of children in the Sissala west district of Ghana, Curr. Res. J. Soc. Sci. 4 (2) (2012) 86–92 [Internet] Available from: http://ezp-prod1.hul.harvard.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=lhh&AN=20123208541&site=ehost-live&scope=site; http://maxwellsci.com/print/crjss/v4-86-92.pdf.

[29] S. Amakye, Coping with Household Food Insecurity during the Lean Season: Strategies Employed by Smallholder Farmers in Navrongo, Ghana, University of Bergen, 2017.

[30] A.M. Prentice, Clinical implications of new insights into hepcidin-mediated regulation of iron absorption and metabolism, Ann. Nutr. Metab. 71 (3) (2017) 40–48.

[31] Z. Grover, L.C. Ee, Protein energy malnutrition, Pediatr. Clin. N Am. 56 (5) (2009) 1055–1068.

[32] Peace Corps Ghana, Sheabutter Processing, 2015 [Internet] Available from: https://www.youtube.com/watch?v=V95gT6fHZHU.

[33] W. Leong, B. Lonnerddal, Iron nutrition, in: G. Andersson, M. G (Eds.), Iron Physiology and Pathophysiology in Humans Nutrition and Health Series, Humana Press, 2012, pp. 91–92.

[34] J. Sadighi, K. Mohammad, R. Sheikholeslam, M.A. Amirkhani, P. Torabi, F. Salehi, et al., Anaemia control: lessons from the flour fortification programme, Publ. Health 123 (12) (2009) 794–799 [Internet]. Elsevier Ltd Available from: http://www.ncbi.nlm.nih.gov/pubmed/19914671.

[35] UNICEF South Africa, The Department of Health South Africa, A Reflection of the South African maize Meal and Wheat Flour Fortification Programme (2004 to 2007), 2007.
[36] M. Venkesh Mannar, Successful food-based programmes, supplementation and fortification, J. Pediatr. Gastroenterol. Nutr. 43 (2006) S47–S53.
[37] K.L. Beck, C.A. Conlon, R. Kruger, J. Coad, Dietary determinants of and possible solutions to iron deficiency for young women living in industrialized countries: a review, Nutrients 6 (9) (2014) 3747–3776.
[38] M. Dreher, in: A. Bendich, W. Bales (Eds.), Nutrition and Heath: Dietary Fiber in Health and Disease, Wimberley, Springer International Publishing, 2018.
[39] C. Wong, Iron deficiency anaemia, Paediatr. Child Heal. (United Kingdom) 27 (11) (2017) 527–529.
[40] S. Bala, B. Tarfa, S. Ado, M. Ishiyaku, M. Makeri, U. Sani, Nutrient and anti-nutrient compositions of new crop varieties of cowpea (vigna unguiculata L.) and maize (Zea mays L.), Niger J. Nutr. Sci. 33 (1) (2012) [Internet] Available from: https://www.ajol.info/index.php/njns/article/view/84759.
[41] M. Hussain, A. Basahy, Nutrient composition and amino acid pattern of cowpea (Vigna unguiculata (L.) Walp, Fabaceae) grown in the Gizan area of Saudi Arabia, Int. J. Food Sci. Nutr. 49 (2) (1998) 117–124.
[42] M.J. Messina, Legumes and soybeans grown foods: overview of their nutritional profiles and health, Am. J. Clin. Nutr. 70 (1999) 39–4504.
[43] A. Das, P.K. Ghosh, Role of legumes in sustainable agriculture and food security: an indian perspective, Outlook Agric. 41 (4) (2012) 279–284.
[44] A. Stone, A. Massey, M. Theobald, M. Styslinger, D. Kane, D. Kandy, et al., Innovations that nourish the planet: Africa's indigenous crops, Afr. Indig. Crops (2011).
[45] D.I. Gernah, M.O. Atolagbe, C.C. Echegwo, Nutritional composition of the African locust bean (Parkia biglobosa) fruit pulp, Niger. Food J. 25 (1) (2007) 190–196.
[46] B.A.Z. Abu, A.K. Anderson, F. Vuvor, M. Steiner-Asiedu, Relationship between food security and irrigation dams: the case of Sissala west district of the Upper West region of Ghana, Curr. Res. J. Soc. Sci. 2 (2) (2010) 123–126.
[47] S.F. Oulaï, F.M.T. Koné, A.P. Amedée, J.T. Gonnety, B.M. Faulet, L.P. Kouamé, Impact of cooking times on some nutritional and anti-nutritional factors of Ivorian breadfruit (Artocarpus altilis) flour, J. Biotechnol. Bioeng. Res. 2 (3) (2014) 34–46.
[48] R.O. Nyumuah, T.-C.C. Hoang, E.F Amoaful, R Agble, M Meyer, J.P. Wirth, D. Panagides, Implementing large-scale food fortification in Ghana: Lessons learned, Food Nutr. Bull. 33 (4/l3) (2012) S293–S300.
[49] B. Abu, W. Oldewage-Theron, R. Aryeetey, Risks of excess iodine intake in Ghana: current situation, challenges, and lessons for the future, Ann. N. Y. Acad. Sci. 1446 (1) (2019) 117–138.
[50] A.-R Abizari, S. Dold, R. Kupka, M.B. Zimmermann, More than two-thirds of dietary iodine in children in northern Ghana is obtained from bouillon cubes containing iodized salt, Public Health Nutr. 20 (2017) 1107–1113.