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Evaluating the impact of home gardening and nutrition education on haemoglobin levels, dietary diversity, and mid-upper arm circumference in Mbororo women: Case of Northwest region, Cameroon

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Abstract

The nutritional status of the Mbororo, a Fulbe minority group in Cameroon's Northwest Region, is often inadequate. This cross-sectional study assessed the impact of a home garden project combined with nutrition education on the nutritional status of Mbororo women, using dietary diversity score (DDS), mid-upper arm circumference (MUAC), and haemoglobin levels as indicators. Data were collected from 70 healthy, non-pregnant Mbororo women aged 65 years or younger. These women were randomly selected from communities with and without home gardens. Women in home garden communities had significantly higher mean DDS (5.4 ± 0.9) than those in non-garden communities (4.2 ± 0.7; p = 0.001), indicating improved dietary quality. However, no significant differences were found in MUAC or haemoglobin levels between groups. Anaemia prevalence across all communities was 52.9 %, a severe public health concern, with 27.1 % of women underweight and 15.8 % overweight, highlighting the double burden of malnutrition. While home gardens improved dietary diversity, they did not resolve broader nutritional challenges. The study concludes that addressing malnutrition in minority communities requires integrated, nutrition-sensitive interventions. These should include nutrition education, home gardening alongside small-scale livestock rearing and fish farming to enhance access to iron-rich foods and diversify nutrient sources. Such approaches are vital for improving long-term nutrition and health outcomes in underserved populations like the Mbororo.

Keywords: food-based intervention, minority community, nutrition education, overweight and underweight

1 Introduction

Minority communities like the Mbororo agro-pastoralists from the Fulbe ethnic group, in Cameroon's Northwest Region (NWR) often face severe food and nutrition insecurity due to limited access to essential resources (Pelican, 2008). These communities make up about 10 % of the region's population and live on the fringes of urban areas (Ebile *et al.*, 2020, 2021, 2022). They are divided into two subtribes, Jaafun and Aku, and inhabit scattered settlements across the grassland region, ideal for cattle grazing (Pelican, 2012). Mbororo men often leave for extended periods during transhumance, making food access difficult for women who rely on stored dry food and butter sales for income (Ebile *et al.*, 2020). This nomadic lifestyle has also led to recurring land-related conflicts with other ethnic groups (Pelican, 2011). As with many minority communities, the Mbororo struggle with malnutrition, maternal mortality, and child morbidity (Beyene *et al.*, 2015). A mix of nomadic livelihoods, land-tenure conflicts, social exclusion, language

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barriers, and poor service coverage keeps Mbororo communities on urban fringes.

The nutritional challenges faced by Mbororo women are reflected in broader public health concerns, such as anaemia, a common global deficiency primarily caused by iron deficiency. (DeLoughery, 2017). About 70 % of the body's iron is bound to haemoglobin, which enables red blood cells to transport oxygen (Gupta, 2014). Thus, haemoglobin concentration is a key indicator for assessing iron deficiency (WHO, 2011). Globally, an estimated 1.62 billion people are affected by anaemia (Alzaheb & Al-Amer, 2017). In Cameroon, prevalence is particularly high among children, reaching 77 % in those aged 9–11 months (Hélène *et al.*, 2020). Another critical measure of nutritional status is the Dietary Diversity Score (DDS), an index for assessing nutrient adequacy and food access (Kennedy *et al.*, 2010). Higher DDS values are linked to more balanced, nutrient-rich diets, while low DDS has been associated with malnutrition, cardiovascular disease, and obesity (Azadbakht *et al.*, 2006). Given the limited access to diverse food among minority communities, tracking DDS offers a practical tool for assessing the double burden of malnutrition, encompassing both undernutrition and overnutrition. Infection burdens (e.g., malaria) common in the Northwest Region can also depress haemoglobin, complicating attribution of anaemia solely to diet.

Mid-upper arm circumference (MUAC) is a simple, reliable tool for assessing malnutrition, especially in low-resource settings (Das *et al.*, 2020). Though BMI has been traditionally used, MUAC is now preferred for its ease and low logistical demands. Studies confirm MUAC's effectiveness in identifying undernutrition, particularly among women, and its suitability for large-scale nutrition screening and monitoring programs (Tang *et al.*, 2013). When combined with haemoglobin concentration and DDS, MUAC offers a more comprehensive picture of nutritional status and can help identify the presence of both under- and overnutrition in vulnerable communities like the Mbororo.

Home gardens, or backyard gardens, offer a practical, food-based strategy for addressing nutrition insecurity in resource-poor communities lacking basic health services (Ebile *et al.*, 2022). Located near homes, these gardens have been shown to enhance food security and empower women socially and economically (Ruel *et al.*, 2018). They promote the cultivation of diverse and indigenous vegetables, increasing household access to nutritious foods (Ebile & Wünsche, 2021). Despite this promise, more evidence is needed on their effects on malnutrition indicators such as dietary diversity, anaemia, and undernutrition in vulnerable populations (IFPRI), 2016). Supplementation often fails in low-income settings due to limited access and affordability, increasing interest in sustainable, food-based solutions like home gardens (Feyrer *et al.*, 2017). Although some studies support the role of home gardens in improving nutrition, findings remain inconsistent (Osei *et al.*, 2017). When combined with nutrition education, home garden projects can further enhance dietary practices by increasing awareness of nutrient needs, food preparation, and hygiene, thereby maximizing the nutritional impact of the foods produced (Ruel *et al.*, 2018; Osei *et al.*, 2017). Factors such as gender, land access, and household size influence their success (Gwacela *et al.*, 2024).

As a result, there is interest in exploring the impact of food-based interventions, such as home gardens and nutrition education, on micronutrient deficiencies in minority communities such as the Mbororos. To our knowledge, a limited number of studies have published data from a home gardens project directly associated with dietary quality, anthropometry, and biochemical measurements such as anaemia as the nutritional outcome in any minority community setting. This study aims to fill this critical gap by examining how home garden projects impact nutritional outcomes, specifically focusing on dietary quality, anthropometric measurements, and biochemical indicators of anaemia, within a minority community context. Our objectives are to: 1) Assess nutritional outcomes, including mid-upper arm circumference (MUAC), dietary diversity score (DDS), and the prevalence of nutritional anaemia, among Mbororo women in communities with and without home garden projects; 2) Analyse the associations between these nutritional outcomes; and 3) Identify additional findings with potential nutritional significance within the context of the home garden initiative.

2 Materials and methods

2.1 Context of the study

2.1.1 Study area

This study evaluated the "Eco-sustainable gardens empowering Mbororo minority women" project, initiated by the University of Hohenheim (Germany), MBOSCUDA (Mbororo Social and Cultural Development Association), and the Mbororo community in Cameroon's Northwest Region (NWR). The project aimed to improve access to fresh vegetables, such as chilli peppers, amaranth and fluted pumpkin, and provide income for Mbororo women. The project was implemented in seven locations across the Mezam (Akum, Mile 9, Banjah, Sabga and Ntambang) and Menchum (Upkwa, Lugere and Njinjam) divisions. Although the project covered seven communities, a random sample of four communities was selected for this study due to budgetary and logistical constraints. This region with geographical coordinates between 5.5°–7.0° N and 9.75°–11.25° E, has a savanna climate, with temperatures of 13–25°C and rainfall of 1500–2000 mm from mid-March to mid-October (Nformi *et al.*, 2014).

Fig. 1: *A map of Cameroon and the map of the Northwest region, locating the study sites in the Mezam and Menchum divisions, where the home garden project was initiated within seven Mbororo communities.*

2.1.2 Home garden intervention

The home-garden and nutrition-education intervention was implemented from 2017 to 2018 across four Mbororo communities. Stakeholders, including government officials, NGOs, and local communities participated in workshops to design and adapt the project. Women received training in nursery management, horticultural practices, and nutrition education, with a focus on diet diversity, vitamins, and hygiene. Garden inputs were provided in the first year. Over the course of two years, women attended regular training sessions. The gardens included nutrient-rich (e.g., amaranth), marketable (e.g., chilli pepper), and indigenous (e.g., jute mallow) vegetables. A total of 46 gardens were established for 114 women with a total area of 27,668 m2. The study focused on those who owned and managed these gardens (further details on the project see Ebile *et al.*, 2022).

2.2 Research design

2.2.1 Selection and evaluation of target communities

The study involved four Mbororo communities: two with home gardens provided by the project (treatment), randomly selected from Mezam and Menchum divisions, and two control communities with no home gardens were purposefully chosen for their similar socioeconomic conditions (Fig. 2). The project involved seven communities, each comprising 25–50 households. These were small, semi-nomadic communities. A total of 70 women who met the eligibility criteria (being neither pregnant nor sick, and being under 65 years old) participated in the project. These exclusions were based on evidence that pregnancy, illness, or supplements can distort nutrient levels (Alzaheb & Al-Amer, 2017).

Two years after the gardens were established, data were collected simultaneously across all sites (cross-sectional study) to assess the impact of the intervention. Data were collected through interviews, focus group discussions and participatory observations.

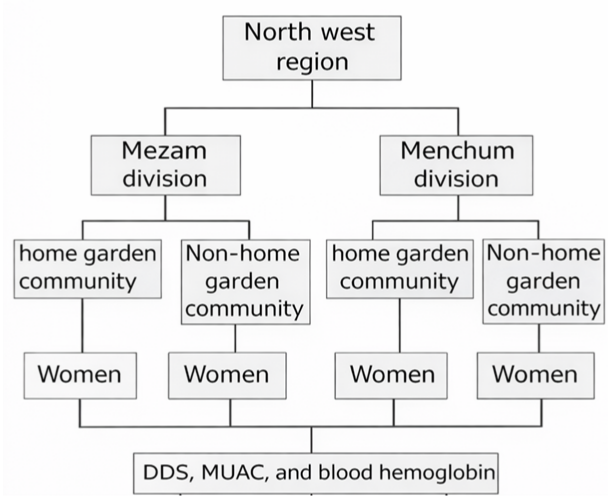

Fig. 2: *Schematic representation of the research design.*

Ethical approval was obtained from the University of Bamenda, Faculty of Health Sciences (ID: 2018/0054UBa/FHS/IRA, approved on 20 July 2018). Informed consent was collected from all participants. Structured pre-coded open- and closed-ended questionnaires were used to assess dietary diversity. MUAC data were collected by trained staff, and a medical doctor used URIT-12 haemoglobinometer to measure haemoglobin levels.

2.2.2 Dietary diversity score (DDS)

Endline data (24-hour dietary recall, MUAC and haemoglobin) were collected at the end of the second harvest season in 2018. Dietary data were collected using the 24-hour recall method, whereby Mbororo women reported all meals, drinks, and snacks consumed the previous day (Kennedy *et al.*, 2010). This method is simple and effective, and is commonly used in dietary studies. The dietary diversity questionnaire, based on the 13-food group standard of the Food and Agriculture Organization of the United Nations (FAO), was designed to assess micronutrient adequacy (Kennedy *et al.*, 2010) (Table 1). According to Kennedy *et al.* (2010), nutrient inadequacy occurs when intake falls below individual requirements. This grouping enabled accurate calculation of individual dietary diversity scores (DDS), which were used to evaluate the quality of the study population's diet.

Table 1: *Determination of individual dietary diversity from thirteen food groups and food examples from the diet of the Mbororo people.*

Food groups	*Food examples*
Cereals	Corn/maize, rice, wheat, sorghum, millet, bread, noodles, porridge, spaghetti, local meals, e.g., fufu corn, koki corn, fufu akra, corn pap, pufpuf, cornchaff, biscuit
white roots and tubers	Sweet potatoes, yams, cassava, Irish potato, cocoyam, white carrot, gari, water fufu, akra cassava, cassava flour, potato flour, potato chips, fufu cassava (*kumkum*), achu, bobolo, plantain
Vitamin A-rich vegetables and tubers	pumpkin, carrot, sweet potato
dark green leafy vegetables	fluted pumpkin, *anchia*, huckleberry, bitter leaves, amaranth, cassava leaves, *folere*, Chinese cabbage, cabbage, cowpea, pumpkin leaves, *lalo*, *caricachee*, cocoyam leaves, green beans, broccoli, carrot greens, chilli green, lettuce
Other vegetables	onion, tomatoes, green, celery, waterleaf, cucumbers, leeks, lettuce, mushrooms, green beans, okra, leaks, eggplant, red cabbage, red sweet pepper
Vitamin A-rich fruits	mango, cantaloupe, apricot (fresh or dried), papaya, peach, passionfruit, 100 % fruit juice made from these fruits
Other fruits	apple, avocados, bush mango, pineapple, Chinese apple, watermelon, wild berries, banana, tangerine, oranges, guava, lemonade, orange, grapefruit, coconut flesh
meat organ	beef and lamb livers, kidney, heart or other organ meats or blood-based foods
fresh meat	beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds, insects, dog, cow meat, rat mole, squirrel, bush fowl, snake
Eggs	eggs
fish and seafood	fresh or smoked fish or shellfish, mudfish, crayfish
legumes, nuts and seeds	beans, dried peas, lentils, nuts, groundnut, soya beans, cowpea, foods made from these: peanut butter, soya bean milk, groundnut sweets, groundnut soup, beans sauce, cornchaff, koki beans
milk and milk products	milk, cheese, yoghurt, butter, locally fermented milk

Note: The names of the foods on the table were common and indigenous so that the respondents could easily understand.

Groups 1 and 2 formed "starchy staples"; groups 3 and 6 were "vitamin A-rich fruits and vegetables with red palm oil"; groups 5 and 7 were combined into "other fruits and vegetables"; and groups 9 and 11 were merged as "meat and fish". These consolidated categories provided a more precise representation of dietary diversity and were used to calculate the Dietary Diversity Scores (DDS) for each respondent in the study.

2.2.3 *Mid-upper arm circumference data collection*

MUAC measurements were taken at the end of the second harvest season, two years into the project, using standardized anthropometric protocols. MUAC reflects both subcutaneous fat and muscle mass, making it a reliable indicator of nutritional status (Tang *et al.*, 2017). Measurements were conducted on the left arm of all the participants in the study: the arm was bent, the distance from the shoulder to the elbow was measured, the midpoint marked. With the arm relaxed, a non-stretchable tape was wrapped around the marked point without compressing the skin, and the circumference was recorded to the nearest millimetre. Based on recent African studies, MUAC values below 24 cm indicate underweight, while values of 30–32.9 cm indicate pre-obesity, and those ≥ 33 cm suggest obesity (Eleraky *et al.*, 2021). MUAC values ≥ 30 cm are considered overweight (Van Tonder *et al.*, 2019). This method provided a quick, low-cost way to assess adult malnutrition in the study population.

2.2.4 *Haemoglobin concentration measurements*

A medical doctor assessed nutritional anaemia in women from both garden and non-garden communities using a URIT-12 haemoglobinometer (Kim *et al.*, 2013). Capillary blood was collected under sterile conditions using: disposable gloves, alcohol swabs, lancets, capillary tubes, gauze pads, haemoglobin strips, and medical waste containers. Each woman was tested privately with sterile materials. After massaging and cleaning the middle finger, a prick was made to collect blood in a capillary tube. The sample was applied to a haemoglobin strip, and all materials were disposed of safely. Haemoglobin levels were interpreted according to WHO standards: ≥ 120 g L^{-1} indicated no anaemia, 110–119 g L^{-1} mild anaemia, 80–109 g L^{-1} moderate anaemia, and < 80 g L^{-1} severe anaemia (WHO, 2011). Malaria parasitaemia or inflammatory markers were not assessed; therefore, haemoglobin values cannot distinguish iron-deficiency anaemia from anaemia of inflammation.

2.3 *Data analysis*

Data were analysed using SPSS (version 22, IBM). Key outcomes included mean Dietary Diversity Score (DDS), haemoglobin levels, anaemia prevalence, and MUAC. Comparisons were made between home garden (treatment) and non-garden (control) communities using means, standard deviations, and population percentages. Chi-square tests assessed associations between groups at a significance level of $p < 0.05$. At the same time, t-tests evaluated differences in mean nutrition outcomes at $p < 0.05$. Results were presented in tables and figures, highlighting the nutritional impact of the home garden intervention.

Table 2: *Sociodemographic, nutritional (MUAC), and haemoglobin status, and dietary diversity among women respondents.*

	Communities			
Variable	*All*	*with HG*	*without HG*	*P value*
Women (N)	70	34	36	NS
Married (%)	67.1	58.8	75	NS
Mezam division (%)	47.1	52.9	41.7	NS
Menchum division (%)	52.9	47.1	58.3	
Aku tribe (%)	52.9	47.1	58.3	NS
Jaanfun tribe (%)	47.1	52.9	41.7	
Age (years)	37.4 ± 14.6	35.5 ± 11.4	39.1 ± 17.0	NS
< 36 years (%)	54.3	58.8	50	
36–59 years (%)	32.8	41.2	25	*
> 59 years (%)	12.9	0	25	
MUAC* (cm)	26.6 ± 3.8	26.5 ± 3.5	26.6 ± 4.2	NS
Underweight (%)	27.1	23.5	30.6	
Normal (%)	57.1	61.8	52.7	NS
Pre-obesity (%)	7.1	11.8	2.8	
Obesity (%)	8.7	2.9	13.9	
Overweight† (%)	15.7	14.7	16.7	NS
Haemoglobin‡ ($g L^{-1}$)	11.7 ± 1.9	11.7 ± 1.9	11.7 ± 1.8	NS
No anaemia(%)	47.1	44.1	50.0	NS
Mild anaemia (%)	21.4	23.5	19.4	
Moderate anaemia (%)	25.7	26.5	25.0	
Severe anaemia (%)	5.7	5.9	5.6	
Anaemia§(%)	52.9	56	50	*
DDS (SD)	4.8 ± 0.9	5.4 ± 0.9	4.2 ± 0.7	***
Below mean DDS (%)	38.6	5.7	32.9	
Above mean DDS (%)	61.4	42.9	18.6	***

HG = home garden; Significant difference *at $p < 0.1$, **at $p < 0.05$, ***at $p < 0.0005$; *mid-upper arm circumference; †sum of pre-obesity + obesity; ‡Haemoglobin (Hb); no anaemia, mild anaemia, moderate anaemia, and severe anaemia are defined as Hb ≥ 120 $g L^{-1}$, 110–119 $g L^{-1}$, 80–109 $g L^{-1}$ and Hb < 80 $g L^{-1}$, respectively; §all respondents with some kind of anemia. DDS = dietary diversity score.

3 Results

The average age of the participating women was 37 years, with 85.5 % them being married. Respondents were nearly evenly distributed between the Aku (52.9 %) and Jaafun (47.1 %) sub-tribes, and between garden (48.6 %) and non-garden (51.4 %) communities (Table 2). Women in garden communities who owned home gardens received nutrition education, while those in non-garden communities did not participate in the project nor receive related education.

3.1 Nutrition outcomes of communities with and without home gardens

3.1.1 Assessment of MUAC in communities with and without home gardens

The average MUAC across communities exceeded the underweight cutoff of 24 cm, at 26.6 ± 3.8 cm (Table 2). Also, there was no statistically significant difference between the average MUAC value of the communities with home gardens and those without home gardens. Nevertheless, averagely across communities, 27.1 % of respondents were underweight (with MUAC equal to or greater than 24 cm), and 15.7 % of respondents were overweight, including pre-obesity and obesity; however, average MUAC values of communities with and without home gardens were not statistically different.

3.1.2 Assessment of the prevalence of anaemia in communities with and without home gardens

Haemoglobin levels showed no significant difference between home garden and non-garden communities (Table 2). Anaemia prevalence exceeded 40 % in all groups, indicating a major health concern. Anaemia was common in both garden and non-garden communities, with no statistically significant difference between them. Moderate anaemia was the most common, followed by mild anaemia. Severe anaemia remained under 6 % in both groups.

3.1.3 Assessment of DDS in communities with and without home gardens

The average DDS across all communities was 4.8 ± 0.9 (home-garden 5.4 ± 0.9; control 4.2 ± 0.7); subsequent analyses compare outcomes below vs above this mean (see Table 2). Women in garden communities consumed more milk, fruits, vegetables, vitamin A-rich foods, and dark green leafy vegetables, as well as foods enriched with red palm oil (Fig. 3). Starchy staples such as cassava and maize were equally consumed across both groups. Iron-rich foods, such as eggs and meat organs, were the least consumed, with fewer than 3 % of respondents reporting intake in either community.

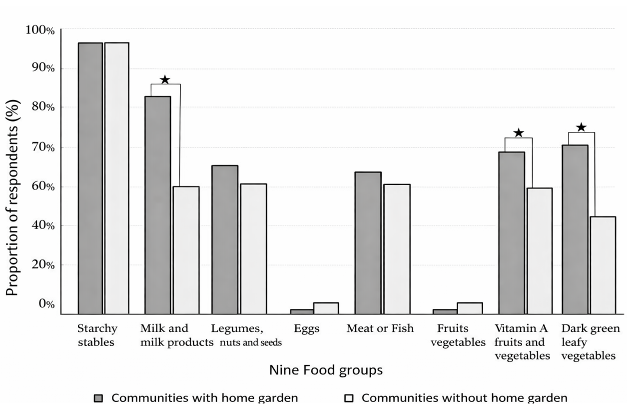

Fig. 3: *Proportion of respondents consuming the various food groups within the communities with and without home gardens. Note: * food groups that are significantly different between the communities with and without home gardens (chi-square test, $p \leq 0.05$).*

3.2 Assessing the associations between the nutritional outcome measurements

3.2.1 The relation between DDS and MUAC

DDS ranged from three to seven, with a weak positive correlation between DDS and MUAC (r = 0.111), although this correlation was not statistically significant. However, when respondents were grouped by DDS levels (ranging from seven to three), a pattern emerged: none of the women with a DDS of seven were underweight, while signs of underweight increased as DDS decreased (Fig. 4). This suggests a potential link between lower dietary diversity and undernutrition, although it was not statistically confirmed in the overall regression analysis.

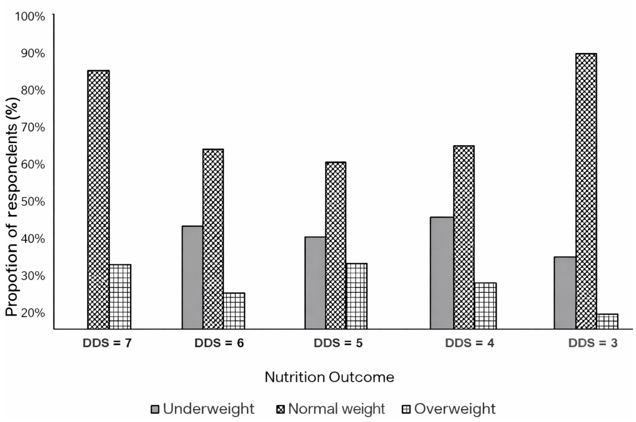

Fig. 4: *Nutrition status in the different groups of respondents with different dietary diversity score (DDS).*

3.3 The relation between DDS and anaemia

Using the sample mean DDS = 4.8 as the threshold (see Table 2 for the distribution below/above the mean), severe anaemia was 11.1 % among women with DDS < 4.8 and 2.0 % among women with DDS ≥ 4.8; moderate anaemia was 29.6 % vs 23.3 %, respectively (r = 0.008). A very weak correlation was found between DDS and haemoglobin levels (r = 0.008), with no statistical significance. However, severe anaemia was more prevalent (11.1 %) among women with below-average DDS, compared to 2 % in those above. Moderate anaemia affected 29.6 % of women with below-average DDS and 23.3 % with above-average DDS, suggesting a trend despite no significant correlation.

3.4 Interesting findings with nutrition implications

3.4.1 Impact of red palm oil on DDS

The food group "vitamin A-rich fruits and vegetables with red palm oil" had high a value, with values over 90 % in garden communities and 75 % in non-garden communities. However, this was largely due to red palm oil, which is very rich in vitamin A. When red palm oil was excluded, only 29.4 % of the participants in garden communities and 11.1 % participants in non-garden communities consumed other vitamin A-rich fruits and vegetables, such as mango, pumpkin, and papaya. Thus, red palm oil alone contributed 60.6 % and 63.9 % to the intake of this food group in garden and non-garden communities, highlighting its significant impact on DDS in both groups.

3.5 Nutritional empowerment of the women

Qualitative interviews, focus groups, and observations revealed that women who participated in the garden project gained greater control over food, income, and land. They asserted independence and ownership of garden plots and their

Table 3: *Nutritional value of the different vegetable types grown in the home gardens.*

Benefits	*Vegetable varieties*	*Nutritional value*
Income-generation	Fluted pumpkin *(Telfairia occidentalis)*	Rich in vitamins A and C; high in potassium, phosphorus, magnesium; moderate in calcium, sodium, copper, iron, and magnesium.
	Hot pepper *(Capsicum annum)*	Good source of amino acids, fatty acids, and minerals including sodium, potassium, calcium, zinc, magnesium, iron, and manganese.
	Waterleaf *(Talinum triangulare)*	High in minerals, vitamins, crude protein, amino acids, and ascorbic acid.
Nutrient-rich	Eggplant *(Solanum melongena)*	Good source of aspartic acid, tropane, flavonoids, lanosterol, gramisterol, steroid alkaloids, glycoalkaloids, histidine, nasunin, oxalic acid, solasodine, ascorbic acid, and tryptophan.
	Amaranth *(Amaranthus spp.)*	High in protein and dietary fibre; good source of calcium, iron, manganese, and magnesium.
	Okra *(Abelmoschus esculentus)*	Good source of minerals (calcium, phosphorus) and vitamins (A, C, B1, B2, B3).
	Chinese cabbage *(Brassica rapa subsp. pekinensis)*	Good source of minerals (potassium, calcium, magnesium, manganese, sodium) and vitamins C and E.
Indigenous	Jute mallow, "lalo" *(Corchorus olitorius)*	Contains minerals (potassium, iron) and vitamins C and A.
	"Folere" *(Hibiscus sabdariffa)*	Abundant in minerals (sodium, potassium, calcium, magnesium, phosphorus) and vitamins (A, B1, B2, B3, C).
	"Caricachee" *(Sesamum radiatum)*	Good protein source with minerals such as iron and magnesium.
	"Bitter leaves" *(Vernonia amygdalina)*	Rich in minerals (iron, phosphorus, calcium, potassium, zinc, copper) and acids (folic acid, ascorbic acid).

products. They also used income from sales to buy essentials like salt and oil. Their sense of empowerment was reflecting pride in their financial autonomy, however, short or incomplete modest the earnings.

From observation, there was an increase in self-confidence among women in the home garden group, who reported they no longer rely on their husbands for financial support after earning income from vegetable sales. Nutrition education from the garden project had a substantial impact, shifting perceptions of vegetables from side dishes to essential nutritional components. Women began cooking more indigenous vegetables for their families. some participants attested that they now encourage their children to eat eggplants daily due to its health benefits. Hygiene practices of the whole family also improved. Over 80 % of women noted that they were not aware of the nutritional benefits of milk to adults, nor the health risks associated with drinking uncooked milk. All the women also gained valuable horticultural skills, allowing them to maintain year-round vegetable gardens. Table 3 summarizes the vegetables grown in all gardens across all the communities. Indigenous vegetables like "*Folere*" (*Hibiscus sabdariffa*) and "*Caricachee*" (*Sesamum radiatum*) were the most commonly consumed, while hot pepper (100 %) was the most cultivated in all gardens. The nutrition education component increased awareness of the importance and nutritional value of vegetables among women in the communities, as well as improved hygiene practices, ultimately contributing to improved health outcomes in the participating communities.

4 Discussion

4.1 Comparison of the DDS, MUAC, and haemoglobin levels of the women of home gardens with non-home garden communities

Despite the home garden intervention, anaemia and underweight remained highly prevalent, alongside emerging overweight, indicating a persistent double burden of malnutrition. Nevertheless, women in home garden communities achieved significantly higher dietary diversity, consuming more nutrient-rich foods such as milk, fruits, vegetables, vitamin A-rich foods with red palm oil, and dark green leafy vegetables. Anaemia prevalence exceeded the World Health Organization threshold for a severe public health problem (WHO, 2011), consistent with broader patterns observed among women in sub-Saharan Africa (SSA) (Stevens *et al.*, 2022). Among Mbororo women, structural barriers, including limited access to clean water, healthcare, and culturally appropriate services, likely contribute to persistently high anaemia rates (Nyuyki *et al.*, 2017).

The home garden intervention did not reduce nutritional anaemia, likely because iron deficiency, primarily addressed through animal-source foods. Haem iron from meat, fish, eggs, and organ meats is more bioavailable than non-haem iron from plant sources (Gupta, 2014), yet consumption of these foods was very limited among participants. Their livelihood strategies that prioritise selling poultry, eggs, and small livestock rather than household consumption may further constrain dietary iron intake. Although legumes and dark green leafy vegetables provide non-haem iron, their consumption was also low, consistent with patterns observed across SSA, including Cameroon (Janmohamed *et al.*, 2024). These findings align with earlier studies among Mbororo women linking anaemia to insufficient intake of iron-rich foods (Ebile *et al.*, 2020). A small but concerning proportion of women were severely anaemic, often associated with infection and limited access to healthcare in remote communities. For instance, communities with home gardens like Banjah and Njinjam lacked nearby health facilities, increasing the risk of anaemia related complications such as fatigue. Most cases were moderate or mild, underscoring the need for integrated interventions that combine improved access to iron-rich foods with strengthened healthcare services.

Although most women were not underweight and no significant differences in MUAC were observed between garden and non-garden communities, substantial MUAC variability indicated a double burden of malnutrition (DBM), with both underweight and overweight evident. DBM is increasingly common in low- and middle-income countries and is associated with changing food systems, sedentary lifestyles, and greater availability of inexpensive processed foods (Popkin *et al.*, 2020). In this study, overweight prevalence was nearly comparable to underweight, demonstrating that DBM affects even marginalised populations traditionally viewed as undernourished, consistent with findings among rural farmers in Tanzania and Mozambique (Eleraky *et al.*, 2021). High reliance on carbohydrate-dominated diets may partly explain overweight patterns, as observed in other African contexts (Melaku *et al.*, 2018), while severe underweight was rare and may reflect non-dietary factors such as illness or metabolic variation (Jeemon *et al.*, 2009). Importantly, the home garden intervention improved dietary diversity, with women in garden communities achieving a significantly higher DDS than the control group. This supports the idea that nutrition-sensitive agricultural interventions can enhance diet quality in DBM contexts, a concept also demonstrated by Fiorella *et al.* (2016).

Our dietary diversity metric used the 9-food-group Women's Dietary Diversity Score (WDDS-9), whereas the globally accepted Minimum Dietary Diversity for Women (MDD-W) is based on 10 food groups and reported as a dichotomous indicator (≥ 5 of 10). By the time, the study was conducted, the 10 food group guidance manual was not yet published. Guidance documents recommend MDD-W for cross-study comparability and program monitoring, and an updated FAO manual consolidates procedures from questionnaire design through analysis (FAO & F H I, 2016). In March 2025, the UN Statistical Commission adopted MDD as a Sustainable Development Goal (SDG) indicator for women, with FAO and UNICEF as co-custodians; official SDG metadata define the indicator as the percentage of non-pregnant women (15–49 y) consuming at least five of ten food groups in the prior 24 h (FAO, IFAD, UNICEF, 2024). Accordingly, our WDDS-9 results should be interpreted with caution when compared to MDD-W–based estimates.

Dietary recall data showed that women in home garden communities consumed more milk, fruits, vegetables, vitamin A-rich foods with red palm oil, and dark green leafy vegetables, indicating improved dietary quality. These gains likely reflect both increased food availability and enhanced financial and social empowerment associated with home gardening. Milk consumption increased markedly among these women; while milk provides important nutrients. However, excessive cow milk intake in young children has been linked to anaemia (Zhang *et al.*, 2021), highlighting the need for nutrition education that promotes appropriate alternatives such as breastfeeding, goat milk, or camel milk (Muleta *et al.*, 2021). Despite improvements in dietary diversity, intake of iron-rich animal-source foods remained low. Promoting household poultry could improve access to eggs and meat while supporting garden sustainability (Alders *et al.*, 2018). Nonetheless, nutrition outcomes are shaped by broader socio-economic factors, including education, income, healthcare access, and rural livelihoods, underscoring the need for integrated, long-term interventions (Zegeye *et al.*, 2021).

This study identified a weak, non-significant positive relationship between dietary diversity (DDS) and both MUAC and haemoglobin levels, differing from findings reported by Mayimbo *et al.*, (2020). Nevertheless, evidence supports MUAC as a reliable anthropometric indicator linked to age and BMI in low-resource settings (Grellety & Golden, 2016). Given the universal consumption of calorie-dense starchy staples, MUAC may not be strongly influenced by DDS alone. Stratified analysis indicated that lower DDS was associated with a higher prevalence of underweight, suggesting that greater dietary diversity may support improved energy balance by providing a more complete intake of macronutrients (Hall *et al.*, 2012). The weak association between DDS and haemoglobin aligns with research showing that anaemia is influenced by multiple non-dietary factors, including illness, age, and context (Malik *et al.*, 2020), with similar trends observed among women and adolescent girls in other settings (Abriha *et al*., 2014; Olumakaiye, 2013).

4.2 Other findings with nutrition implications

4.2.1 Red oil consumption

Vitamin A–rich foods in this study were largely derived from red palm oil (Elaeis guineensis), a widely consumed cooking fat in Cameroon and across SSA. Although a saturated fat, red palm oil is rich in provitamin A and provides essential energy and nutrients (Scrimshaw, 2000). Most respondents relied more on red palm oil than on vitamin A–rich fruits and vegetables, suggesting its central role in meeting vitamin A needs and reducing the risk of deficiency. This reliance aligns with successful red palm oil–based interventions targeting vulnerable populations (Manorama, 2014). Broader food fortification strategies, such as biofortifying commonly consumed staples and condiments, including oil, salt, or milk, offer complementary approaches for improving micronutrient intake in low-resource settings (Andersson, 2017; Kyamuhangire *et al*., 2013).

4.2.2 Women's empowerment

Women's empowerment through home gardening has been strongly linked to improved nutritional outcomes and greater nutrition knowledge (Heckert *et al*., 2019). In this project, women gained control over land and produce, allowing them to decide whether to consume, share, or sell vegetables, thereby improving both physical and economic access to nutritious foods and addressing key pillars of food and nutrition security. Ownership and participation also contributed to more equitable gender roles, consistent with evidence that women's involvement in agriculture can reduce gender inequalities and strengthen household food security (Otte *et al*., 2018; Harris-Fry *et al*., 2020). Focus group discussions revealed increased self-esteem and financial autonomy, as women used income from vegetable sales to purchase additional foods, further enhancing dietary diversity. These findings align with research showing that income generation and market participation can increase DDS (Koppmair *et al*., 2017). Overall, the home garden intervention improved dietary diversity by expanding access to vegetables and enabling complementary food purchases, supporting broader evidence that diversified diets enhance nutrition and health (Fanzo *et al*., 2013).

Minority communities often experience high levels of micronutrient deficiencies and limited access to healthcare (Bailey *et al*., 2015). Home gardens can reduce this vulnerability by improving access to diverse, nutrient-rich foods and strengthening women's decision-making power, making them an effective nutrition-sensitive agricultural intervention in resource-poor settings (De Brauw *et al*., 2015). This study reinforces evidence that home gardens enhance food and nutrition security by diversifying diets, improving access to micronutrients, and empowering women through control over food production and income (Waage *et al*., 2013). Vegetables commonly grown in these gardens are rich in essential vitamins and minerals, including fluted pumpkin, hot pepper, waterleaf, eggplant, Chinese cabbage, jute mallow, and Hibiscus sabdariffa (Oladoye & Liu, 2022; Naeem & Ugur, 2019; Ebana *et al*., 2019; Choudhary *et al*., 2013). Income from surplus produce sales further improves food access (Ebile *et al*., 2022).

5 Conclusions

This study shows that home gardens together with nutrition education significantly improved dietary diversity among Mbororo women in Cameroon. However, no significant impact was found on haemoglobin levels or MUAC, suggesting that persistent anaemia may be due to a low intake of iron-rich foods. The short study duration and sample size limited the long-term impact assessment on nutritional outcomes. Future interventions should combine home gardening with small-scale livestock rearing, nutrition education, and broader socioeconomic support to effectively combat malnutrition and improve overall health in vulnerable communities.

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Conflict of interest

The authors declare that they have no conflict of interest.

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