

Neglected Micronutrients in the Diets of Rural Ghanaian Women: Intake Levels, Knowledge, and Affordability in the Rural Food Markets

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<u>Abstract</u>

Micronutrient deficiencies (MND) remain a major public health concern, affecting nearly onethird of the global population, with women of reproductive age particularly at risk due to their higher physiological needs. Among the various MNDs, calcium deficiency is common yet understudied in Ghana, where data on calcium intake levels and influencing factors, including population knowledge and economic constraints, are limited. This research examined the levels of calcium intake among Ghanaian rural women, sociodemographic predictors, top food contributors of intake, knowledge about calcium, and the cost of top calcium-providing foods in rural markets.

This study comprised of three components: (i) A secondary analysis of quantitative data of the LinkINg Up project in the Eastern Region of Ghana (ClinicalTrials.gov NCT03869853). The final analysis included 315 women, enrolled over two phases (2019-2020 and 2021-2022). Relevant data collected included dietary intake using three 24-hr dietary recalls covering two weekdays and one weekend day and socio-demographic details (e.g., age, education, marital status). Median calcium intakes were compared to the age-specific Harmonized Average Requirements to assess adequacy. Potential sociodemographic predictors were assessed using a hierarchical mixed model, adjusted for body mass index and energy intake. (ii) A qualitative data collection using focus group discussions with 47 women *gari* (roasted cassava flour) producers participating in an ongoing entrepreneurship project in the same region, assessed women's knowledge and perceptions of calcium and its food sources. (iii) Two rural markets were assessed to identify foods that contributed the most to calcium at the lowest cost. The quantitative analysis showed that the mean age of the women was 44.8 ± 13.4 years. Median [inter-quartile range] calcium intake in the whole sample was 602.7 [424.4, 886.7] mg/day. Over

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70% of women 25 years old and younger had calcium intakes below the recommended levels of 860 mg/day for their age bracket. Almost 61.3% of women who were \geq 25 years old had calcium intake levels lower than recommended. Education level was the only significant predictor and was negatively associated with calcium intake (p=0.01). The top ten food contributors to calcium intake were smoked herring (35.7%), *banku* (stiff porridge made with corn and cassava dough) (13.8%), fried mackerel (6.9%), palm nut soup (6.6%), kontomire (cocoyam leaves) stew (5.6%), and light (tomato-based) soup (3.2%), fufu (cassava and plantain mix) (3.1%), okra stew (2.1%), kenkey Ga (stiff porridge made of processed corn dough) (2.0%), and cooked anchovies (1.8%), in descending order of their contribution to the total intake of calcium in the sample. The qualitative analysis revealed almost all of the women (average age of 34.6 ± 4.4 years) did not recognize calcium by its name, yet they mentioned some of the important food sources correctly. Edible bones in smoked small fish and milk powder were consistently viewed as beneficial for human bone health. Healthcare staff and schools were identified as the two main sources of nutritional information for these women. Different perceived barriers to consuming dietary calcium were identified, including a lack of awareness about the benefits of fish powder, its low market availability, the high price of both fish powder and canned sardines, the perishability of canned sardines once they were opened, and previous negative experiences with foods like okra and *kenkey*. The market assessment demonstrated the foods with the most calcium and lowest cost were fish powder, smoked herring, milk powder, and cocoyam leaves. The cost of a 50 mg increase in calcium would be at most 0.05 USD per day for the mentioned food items. Findings from this study can draw the attention of authorities to calcium as another essential micronutrient that has been neglected in previous research, programs, and policies for the population in Ghana.

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<u>Résumé</u>

Les carences en micronutriments (CEM) restent un problème de santé publique majeur, affectant près d'un tiers de la population mondiale, les femmes en âge de procréer étant particulièrement exposées en raison de leurs besoins physiologiques plus élevés. Parmi les différents CEM, la carence en calcium est courante mais sous-étudiée au Ghana, où les données sur les niveaux d'apport en calcium et les facteurs d'influence, notamment les connaissances de la population et les contraintes économiques, sont limitées. Cette recherche a examiné les niveaux d'apport en calcium chez les femmes rurales ghanéennes, les prédicteurs sociodémographiques, les principaux contributeurs alimentaires à l'apport, les connaissances sur le calcium et le coût des aliments les plus riches en calcium sur les marchés ruraux.

Cette étude comprenait trois volets : (i) Une analyse secondaire des données quantitatives du projet LinkINg Up dans la région orientale du Ghana (ClinicalTrials.gov NCT03869853). L'analyse finale a porté sur 315 femmes inscrites en deux phases (2019-2020 et 2021-2022). Ls étaient répartis presque également entre les différents niveaux d'éducation. Les données pertinentes collectées comprenaient l'apport alimentaire à l'aide de trois rappels alimentaires de 24 heures couvrant deux jours de semaine et un jour de week-end ainsi que des détails sociodémographiques (par exemple, âge, éducation, état civil). Les prédicteurs sociodémographiques potentiels ont été évalués à l'aide d'un modèle mixte hiérarchique, ajusté en fonction de l'indice de masse corporelle et de l'apport énergétique. (ii) Une collecte de données qualitatives à l'aide de discussions de groupe avec 47 femmes productrices de *gari* (farine de manioc) participant à un projet d'entrepreneuriat en cours dans la même région, a évalué les connaissances et les perceptions des femmes sur le calcium et ses sources alimentaires. Les apports médians en calcium ont été comparés aux exigences moyennes

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harmonisées spécifiques à l'âge afin d'évaluer leur adéquation. (iii) Deux marchés ruraux ont été évalués pour identifier les aliments qui contribuaient le plus au calcium au moindre coût. L'analyse quantitative a montré que l'âge moyen des femmes était de 44.8 ± 13.3 ans. L'apport médian en calcium [intervalle interquartile] dans l'ensemble de l'échantillon était de 602.7 [424.4, 886.7] mg/jour. Plus de 70 % des femmes de 25 ans et moins avaient des apports en calcium inférieurs aux niveaux recommandés de 860 mg/jour pour leur tranche d'âge. Près de 61.3 % des femmes âgées de \geq 25 ans avaient un apport en calcium inférieur à celui recommandé. Le niveau d'éducation était le seul prédicteur significatif et était négativement associé à l'apport en calcium (p = 0.01). Les dix principaux aliments contribuant à l'apport en calcium étaient le hareng fumé (35.7 %), le *banku* (pâte de maïs et de manioc) (13.8 %), le maquereau frit (6.9 %), la soupe aux noix de palme (6,6 %), le ragoût de *kontomire* (feuilles de cocoyam) (5.6 %), et soupe légère (à base de tomates) (3.2 %), *fufu* (mélange de manioc et de plantain) (3.1 %), ragoût de gombo (2.1 %), kenkey Ga (un aliment de base à base de pâte de maïs transformée) (2.0 %), et les anchois cuits (1.8%), par ordre décroissant de leur contribution à l'apport total en calcium de l'échantillon. L'analyse qualitative a révélé que presque toutes les femmes (âge moyen de 34.6 ± 4.4 ans) ne reconnaissaient pas le calcium par son nom, mais qu'elles mentionnaient néanmoins correctement certaines des sources alimentaires importantes. Les os comestibles contenus dans les petits poissons fumés et le lait en poudre étaient toujours considérés comme bénéfiques pour la santé des os humains. Le personnel de santé et les écoles ont été identifiés comme les deux principales sources d'informations nutritionnelles pour ces femmes. Différents obstacles percus à la consommation de calcium alimentaire ont été identifiés, notamment le manque de sensibilisation aux avantages de la poudre de poisson, sa faible disponibilité sur le marché, le prix élevé de la poudre de poisson et des sardines en conserve, le

caractère périssable des sardines en conserve une fois ouvertes et les précédents. Expériences négatives avec des aliments comme le gombo et le *kenkey*. L'évaluation du marché a démontré que les aliments contenant le plus de calcium et les moins chers étaient la poudre de poisson, le hareng fumé, le lait en poudre et les feuilles de taro. Le coût d'une augmentation de 50 mg de calcium serait d'au plus 0.05 USD par jour pour les aliments mentionnés. Les résultats de cette étude peuvent attirer l'attention des autorités sur le calcium en tant qu'autre micronutriment essentiel qui a été négligé dans les recherches, programmes et politiques antérieurs destinés à la population du Ghana.

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Contribution to original knowledge

This master's thesis aimed to shed light on the under-studied calcium status among rural women in Ghana by integrating quantitative dietary analysis, qualitative insights from local female farmers, and market assessments. It is the first quantitative study to focus specifically on calcium, whereas previous studies only considered calcium as a secondary nutrient in their analyses. Additionally, this study provided an updated assessment of calcium intake levels in rural women of Eastern Region, with the last reported data from 2008. The qualitative study was the first to report the knowledge of rural women about calcium and its food sources, whereas prior research has focused on the assessment of iron and vitamin A knowledge. The market assessment identified the least expensive calcium contributors to the diet available in rural markets, specifically searching for calcium contributors for the first time in this region of Ghana. The findings from this study highlight the importance of paying attention to calcium, an essential micronutrient often overlooked in research concerning the Ghanaian population.

Contribution of Authors

This thesis assessed the calcium in the diets of rural women in Ghana through assessing its intake levels (a quantitative study), women's knowledge (a qualitative study), and affordability in the market (a market assessment).

The quantitative study (aimed to assess calcium intake levels) was a secondary analysis of data from the *Scaling Up Women's Agripreneurship through Public-Private Linkages to Improve Rural Women's Income, Nutrition, and the Effectiveness of Institutions project in rural Ghana* (referred to as *LinkINg Up*), a quasi-experimental, nutrition-sensitive agricultural intervention conducted in the Eastern Region of Ghana (ClinicalTrials.gov NCT03869853). The principal /co-investigators of this project were Drs. Esi K Colecraft and Naa D Dodoo from University of Ghana, Drs. Grace S Marquis and Nii A. Addy from McGill University, Mr. Roland Kanlisi from Heifer International, and Mr. Evans Lawson from the Upper Manya Krobo District Director of Agriculture. They were involved in the conceptualization and design as well as obtaining ethics approval, implementation, and data collection of the project. Shabnam Hosseini used the data to perform the secondary analysis with the aim of exploring calcium intake levels. Under the supervision of Dr. Marquis, she developed the analysis plan, interpreted the results, and wrote them up.

The qualitative study (aimed to assess the women's knowledge) was embedded in the *Youth and Rural Women Entrepreneurship: Creating and sustaining alternative livelihood options in Ghana.* The individuals involved in this project were Ms. Priscilla Boadi (the project lead), Drs. Grace S Marquis and Diana Dallmann from McGill University, Dr. Thomas Anning-Dorson from the University of the Witwatersrand in Johannesburg, Drs. Richmond Aryeetey, George

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Acheampong and Agartha Ohemeng from University of Ghana, and Mr. Johnson Opoku Boateng and Mr. Daniel Okyere Tweneboah from Association of Ghana Industries. They were involved in the conceptualization, design, and implementation of the project. Shabnam Hosseini in consultation with Dr. Marquis designed the study embedded into this bigger project, designed the qualitative research tools, and coordinated and managed all field activities including training the field staff, team management, data collection, and overseeing the transcription in Ghana. Support of the field work in Ghana was provided by Dr. Agartha Ohemeng. She also contributed to reviewing the thesis.

The market assessment was conducted and conceptualized by Shabnam Hosseini with the aim of assessing the affordability of the calcium-rich foods in rural markets. Dr. Marquis was involved in conceptualizing the market survey. Dr. Ohemeng facilitated the logistics for carrying out the market study.

Shabnam Hosseini performed all data cleaning and quantitative and qualitative analyses and wrote the thesis. Dr. Marquis provided input with the interpretation and presentation of the findings in all parts.

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List of Abbreviations

- BIC Bayesian Information Criterion
- BMI Body mass index
- FAO Food and Agriculture Organization of the United Nations
- FBO Farmer-based organization
- FGD Focus group discussion
- H-AR Harmonized average requirements
- LMICs Low- and middle-income countries
- Mg Milligrams
- MND Micronutrient deficiencies
- MSM Multiple source methods
- URWE Youth and rural women entrepreneurship
- VAM Vulnerability and Assessment Mapping
- WFP World Food Programme
- WRA Women of reproductive age

Chapter 1. Introduction

Micronutrient deficiencies (MND) remain a significant public health concern, impacting nearly one-third of world's population (Han et al., 2022). Having a low-quality monotonous diet has been identified as a risk factor for MNDs (Amugsi et al., 2016; Arimond et al., 2008), especially among women of reproductive age (WRA) and children due to their higher physiological requirements compared to other demographic groups (Martin-Prevel, 2015). A common but under-studied MND among women in low- and middle-income countries (LMICs) is calcium, which plays a vital role in the formation of bones (Cormick & Belizan, 2019). Compared to high-income countries, like the United States of America where the average calcium intake is 934 mg/day, African countries generally have a low average calcium intake ranging between 400 to 700 mg/day (Balk et al., 2017). Rural Ghana has more starchy-dominant diets compared to urban dwellers (Galbete et al., 2017), which increases the risk of calcium deficiency (Amugsi et al., 2016). However, calcium studies are limited among rural Ghanaian WRA (Kobati et al., 2012; Nti, 2008). Much of the existing calcium intake levels data from Ghana are either old or from pregnancy and lactation period of life (Nti, 2008).

There are different factors affecting the calcium intake, and these factors include the population's knowledge and cost of foods (De Vriendt et al., 2009; Masters et al., 2018). There are no studies assessing women's knowledge of calcium in Ghana. However, studies from Nigeria, Kenya, and South Africa documented limited knowledge of calcium and osteoporosis among women (Folasire & Akinrinde, 2017; Sitati et al., 2021; Steyn et al., 2000). Food costs, a component of food environment assessment, are identified as a barrier to achieving a nutrient-adequate diet (Herforth et al., 2020; Novotny et al., 1999). In Ghana, the cost of nutrient adequacy doubled from 1 to 2 USD per day between mid-2010 and 2014, primarily due to the increased cost of

foods rich in vitamin A and calcium (Masters et al., 2018). Assessing the cost and affordability of calcium-rich foods in local markets can help to suggest feasible dietary strategies with the aim of increasing calcium intake.

Overall research aim

This study aims to contribute to our understanding of micronutrient deficiencies among rural women in the Eastern Region of Ghana and to shed light on one micronutrient, calcium, which has been neglected by previous policies in Ghana.

Specific Research Objectives

Quantitative study objectives

- 1- To estimate the dietary calcium intake level and compare it to the recommendations
- 2- To identify the predictors of calcium intake among women in rural Eastern Region of Ghana
- 3- To identify the top food contributors to calcium in the diets of women living in the rural parts of the Eastern Region of Ghana

Qualitative study objectives

- 1. To assess women's knowledge about calcium and its importance for their health
- 2. To investigate food sources of calcium that women know
- 3. To identify the women's sources of nutritional information
- 4. To investigate the perceived barriers of accessing foods containing calcium

Market assessment study objectives

- 1. To identify the least-cost calcium-rich foods in local rural markets
- 2. To suggest affordable, feasible, and culturally appropriate dietary changes to increase women's calcium intake in rural areas

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Chapter 2. Review of the Literature

Calcium landscape in Africa

Calcium is an essential nutrient involved in bone mineralization (Cormick & Belizan, 2019). Over 99% of calcium is stored in the bones and teeth, where it serves as a reserve to maintain stable blood calcium levels during the periods of deficiency (Matikainen et al., 2021). Calcium transport in the intestines, kidneys, and bones is tightly regulated by three hormones: parathyroid hormone, 1,25-dihydroxyvitamin D-3 (active metabolite of vitamin D), and calcitonin (Yu & Sharma, 2023). Humans rely on daily dietary intake of calcium, with requirements varying across different life stages such as growth, pregnancy, and lactation.

There is an absence of a universal biomarker for calcium status assessment in the body. Calcium level in the blood is not a reliable indicator of adequacy, as the body tightly regulates calcium through homeostatic control (Weaver, 2020). Therefore, assessing low calcium intake relies on indirect measures like food balance sheets or national dietary intake surveys (Kapner, 2021). Despite the recognized importance of calcium, the relationship between its intake and health outcomes is inconsistent (Kapner, 2021). Calcium recommendations are primarily based on the bone health outcomes such as osteoporosis. Although calcium deficiency is associated with some diseases including cancer, cardiovascular diseases, and preeclampsia (National Institutes of Health, 2024), it can also reduce bone strength and is associated with osteoporosis in adults (Matikainen et al., 2021). Women are a group at risk of calcium inadequacy due to physiologically increased needs during pregnancy and lactation. Osteoporosis is a commonly cited long-term consequence of calcium deficiency starting from younger ages that can be prevented with adequate daily intake from diet (Institute of Medicine, 2011). A recent meta-

analysis on global osteoporosis prevalence stated a worldwide prevalence of 18.3 % (95% CI: 16.2, 20.7), with Africa showing the highest prevalence at 39.5% (95% CI: 22.3, 59.7) (Salari et al., 2021). However, 39.5 % was reported based on a few African studies included in the metaanalysis which might not represent the prevalence in countries across Africa. Therefore, there is a call for more research on osteoporosis, especially in Sub-Saharan African (Atiase & Quarde, 2020). No data are available for Ghana.

A review of key nutrition policies and programs in Ghana by Aryeetey and Coomson (2022) highlighted government's efforts to address iron, folate, vitamin A, zinc, and iodine deficiencies, which remain public health concerns in the country (Aryeetey & Coomson, 2022). These initiatives include various strategies such as the iron-folic acid supplementation tailored for adolescents and pregnant women, the infant and young child feeding program (Ghana Health Services, 2019), and the mandatory food fortification of wheat flour and vegetable oil (Nyumuah et al., 2012). Fortification of salt with iodine was another initiative to reduce iodine deficiency. There is a notable absence of focus on calcium and vitamin D, probably due to the limited data available (Aryeetey & Coomson, 2022). There is no established calcium supplementation program for at-risk populations in Ghana (Aryeetey & Coomson, 2022), and Aryeetey et al. (2020) advocated for the inclusion of calcium supplements during routine antenatal care visits, but this had not yet been integrated into Ghana's public health policy (Aryeetey et al., 2020). In addition, Ghana faces challenges in livestock production and dairy consumption. While Ghana has its own livestock production (Taylor, 2023), it heavily relies on imports for over 90% of its livestock product consumption. In 2023, an 8 % decline in domestic live cattle population was reported due to high maintenance costs. There are a few large milk factories in Accra and Kumasi engaged in manufacturing and repackaging imported milk products (Ministry of Food

and Agriculture, 2016). The low production of dairy products in Ghana results from different factors including low patronage of dairy farming, low-performing breeds, safety issues, inadequate policies, water shortage, inadequate structure, and poor farmer education (Achaglinkame et al., 2023). The production consequence of these challenges may contribute to low consumption.

Dietary sources of calcium in Ghana

Dietary calcium can come from animal-source foods, plant-source foods, and water (Bourassa et al., 2022). Unlike high-income countries, where the main source of calcium intake is dairy products, LMICs have varied sources of calcium consumption.

Animal-source foods

In Ghana, animal-source foods rich in calcium include dairy products, edible fish bones (commonly in fish powder), eggs, and grasscutter meat (Adu et al., 2017; Agyei-Mensah et al., 2023; Larsen et al., 2000). Regarding milk and dairy products, they are infrequently consumed and are occasionally incorporated into porridge recipes (Kobati et al., 2012). A study among rural pregnant women in Northern Ghana found that 83% did not consume milk at all (Agyei et al., 2021).

Regarding the edible fish bones, research on calcium absorption from fish bones remains limited. However, some relevant studies provide insights into its potential as a calcium source. For example, a double-blinded randomized crossover study has shown that calcium absorption from cod and salmon fish bone powders averaged $21.9 \pm 1.7\%$ and $22.5 \pm 1.7\%$, respectively, which did not differ significantly from the absorption rate of calcium carbonate (CaCO₃) at $27.4 \pm 1.8\%$ in healthy men (Malde et al., 2010). Similarly, an experimental study also found that calcium absorption from Bengali fish was comparable to that from skimmed milk, with rates of $23.8 \pm$

5.6% and $21.8 \pm 6.1\%$, respectively (Hansen et al., 1998). Despite the limited number of studies on calcium absorption from specific fish species, these findings suggest that fish bones could be a viable source of calcium, with comparable bioavailability to more traditional sources. Regarding the eggs and grasscutter's meat as a source of calcium in Ghana, eggs, predominantly the yolk, offer about 57 mg of bioavailable calcium per 100 g (Theobald, 2005). In addition, grasscutter, which is one of the commonly eaten species of game meat in Ghana, especially in rural areas (Ministry of Food and Agriculture, 2016), contains high levels of calcium (approximately 83 mg per 100 g) compared to other meats such as rabbit (22 mg), goat (25.3 mg), chicken (10 mg), and pork (3 mg) (Adu et al., 2017; Jori et al., 1995). The reason for this variation in calcium content has not yet been studied.

Plant-source foods

In Ghana, tomato (10 mg calcium), cabbage (40 mg), cauliflower (22 mg), and cucumber (16 mg) are exotic vegetables frequently consumed, but they are low in calcium content (Nyadanu & Lowor, 2014). In contrast, indigenous vegetables including jute mallow (*Corchorus olitorius*), amaranth (*Amaranthus cruentus*), cocoyam leaves (*Kontomire or Xanthosoma sagittifolium*), garden egg (African eggplant, *Solanum macrocarpon*), okra leaf (*Abelmoschus esculentus*), and baobab (*Adansonia digitata*) (Atuna et al., 2022; Nyadanu & Lowor, 2014) provide calcium in Ghanaian diets, ranging from 63-380 mg per 100 g (Atuna et al., 2022). However, the cultivation practices (soil quality and water) can affect the calcium content of vegetables, and the presence of antinutritive compounds, like oxalate and phytate, can influence the bioavailability of calcium in the intestines (Atuna et al., 2022; Theobald, 2005).

Water

Water represents another source of daily calcium intake, often overlooked in studies evaluating calcium content of the diets (Atuna et al., 2022). Proposals have been made for water fortification as an effective short-term strategy to increase calcium intake (Cormick et al., 2022). Calcium in the water is in ionic form, which makes it bioavailable for humans. Recent studies have revealed that drinkable water in high-income countries typically contains 300 mg/L of calcium (Cormick et al., 2020). However, a study conducted in suburbs of Accra, the capital city of Ghana, found that potable water had calcium concentrations ranging from 14.4 to 43.2 mg/L (Gyamfi et al., 2012). Although there is still no consensus on the correlation between calcium and magnesium in drinking water and their impact on bone health, some evidence show that high-calcium water benefited the Italian and French women's spine and femoral mineral density (Sengupta, 2013).

In addition to sources of calcium, it is crucial to consider both inhibitors and enhancers of calcium absorption, as nutrient interactions occur during intestinal absorption. Table 2.1 provides an overview of dietary inhibitors of calcium, which are primarily found in plant-based foods (Shkembi & Huppertz, 2022; Skibsted, 2016).

The primary site of calcium absorption is in the small intestine, where calcium precipitation through binding with oxalate or phytate happens, thereby diminishing calcium absorption (Skibsted, 2016). Commonly consumed vegetables in Ghana, such as beans and okra, contain high levels of oxalate (Theobald, 2005). Oxalate binds with calcium creating insoluble salts, which reduce the calcium's absorption from the intestine. Ghanaian cuisine also incorporates grains and legumes that contain phytic acid which can bind to calcium as well as other minerals like zinc, iron, and manganese (Theobald, 2005). Moreover, the presence of palmitate in the diet can reduce calcium bioavailability in the intestine due to calcium precipitation (Vavrusova et al.,

2013). Palmitic acid, the predominant saturated fatty acid, is a key component of palm oil, widely used in Ghanaian cooking.

Table 2.1. also illustrates dietary enhancers of calcium. Components such as lactose and casein proteins found in milk may increase the calcium absorption because casein forms phosphopeptides during digestion which prevents calcium from forming insoluble salts with other antinutritive compounds that might be present in the intestines. Vitamin D can be considered another enhancer of calcium absorption because it regulates the transportation of calcium in the intestines and controls the calcium hemostasis (Theobald, 2005).

There are also food preparation practices that increase the bioavailability of calcium but are not commonly practiced in Ghana. The process of nixtamalization involves soaking corn in calcium hydroxide (Palacios-Pola et al., 2022). Although corn is the most frequently used staple in Africa, the practice of nixtamalization is not widely known across African countries (Ekpa et al., 2019). Research has demonstrated that nixtamalization can enhance the calcium content of corn kernels up to 18 times (Bressani et al., 2002).

Calcium intake levels in Ghana

Research conducted in African countries has consistently shown low levels of calcium intake, especially among women (Islam et al., 2024). Studies in The Gambia (Prentice et al., 1993), South Africa (Kolahdooz et al., 2013; Kruger et al., 2011; Motadi et al., 2020), Nigeria (Oladoyinbo et al., 2017), Uganda (Heffron et al., 2022), and Zambia (Muggaga et al., 2023) (Byrd et al., 2021) have highlighted suboptimal calcium intake levels, reaching as low as 186 \pm 159 mg/day in Nigeria. There is a notable absence of Ghana in reviews reporting the calcium intake levels (Islam et al., 2024). In Ghana, while studies have examined the intake of iron, folate, and other micronutrients (Agbemafle et al., 2016; Gernand et al., 2019; Kobati et al.,

2012; University of Ghana et al., 2017; Wegmuller et al., 2020) among women, there are limited studies available on calcium intake levels (Nti, 2008; World Food Programme, 2016). In both Coastal Savannah and Guinea Savannah regions of Ghana, low calcium intake among WRA (mean intake \pm standard deviation: 471 \pm 323.9 mg/d vs. 395 \pm 167.2 mg/d, respectively) was reported (Kobati et al., 2012). The World Food Program highlighted challenges in meeting nutrient requirements, including calcium, among Ghanaian WRA (World Food Programme, 2016). In 2008, Nti (2008) reported that 36% of respondents consumed calcium below 50% of the recommended levels. These few studies reporting inadequate calcium intake among Ghanaian women were cross-sectional, focused on multiple micronutrients rather than specifically on calcium, and are over a decade old (Table 2.2).

Apart from the calcium intake levels, non-dairy sources of calcium and the predictors of calcium intake in rural Ghana have yet to be explored. In studies from other countries, foods such as green leafy vegetables, fish, cereals, and groundnuts have been reported as non-dairy sources of calcium in women's diets (Ignowski et al., 2023; Prentice et al., 1993). Some predictors of calcium intake were mentioned to be sex, age, marital status, and education level in Bangladesh and Uganda (Islam et al., 2023; Muggaga et al., 2023). However, there remains a lack of similar research in rural Ghana.

Knowledge of calcium in Ghana

A strategy in tackling public health issues is enhancing individuals' nutrition knowledge, which is essential for improvements in dietary behavior (De Vriendt et al., 2009). In African countries, excluding Ghana, limited knowledge of calcium and osteoporosis among women is documented using quantitative questionnaires (Folasire & Akinrinde, 2017; Sitati et al., 2021; Steyn et al., 2000). Using quantitative questionnaires when assessing the knowledge of participants limits the

depth of insights into population's understanding of calcium and its importance (Tenny et al., 2024). In Ghana, qualitative studies have primarily explored the knowledge of iron and vitamin A among men and women (Awuah et al., 2021; Omari et al., 2017). Awuah et al. (2021) conducted 48 focus group discussions across various district in Ghana, including participants such as women, adolescent girls, and men. Using thematic analysis, they identified a gap between knowledge of anemia and the health and nutrition behaviors required to reduce it. Similarly, Omari et al. (2017) conducted 25 focus group discussions in two districts of Ghana, highlighting barriers to consuming adequate vitamin A and iron. While there was a notable lack of knowledge about vitamin A, knowledge of iron and its sources was slightly better among their participants.

Qualitative research prioritizes the participants' perspectives, ensuring that the findings are grounded in real-world experiences (Patton, 2015). There are no similar qualitative studies assessing the knowledge of calcium in Ghana. Although the barriers to dairy consumption and knowledge about calcium may differ between LMICs and high-income countries, even studies in high-income countries indicate that participants were uninformed about the importance of calcium and dairy products even though they have access to it (Holland & Moffat, 2017; Marcinow et al., 2017; Rouf et al., 2019).

Cost of calcium-rich foods

The Food and Agriculture Organization of the United Nations (FAO) highlighted the influence of the food environment on dietary choices, emphasizing its importance for developing effective nutrition policies (Downs et al., 2020; Lartey et al., 2016). In 2020, the FAO reported that almost 1.5 billion people globally could not afford diets with adequate levels of all essential nutrients (Herforth et al., 2020). The cost of a nutrient-adequate diet is defined as the minimum daily cost

of foods in a diet that meet the requirements for all essential nutrients (23 micro- and macronutrients) and dietary energy for WRA (Masters et al., 2018). WRA is used in this definition for two reasons. First, their requirements were at the median of the entire population, meaning the least-cost diets for this group represent the median cost for all sex-age groups across the life cycle. Thus, this reference group effectively represents the broader population. Second, WRA are usually a nutritionally vulnerable group, facing higher risks of dietary deficiencies due to social norms and practices that limit their food access, which significantly impacts both them and their children (Herforth et al., 2020). Notably, out of 186 million people who could not afford the cheapest form of daily energy in their countries, 149 million reside in Africa (Herforth et al., 2020). In sub-Saharan Africa (45 countries were included in the analysis), the mean cost of a nutrient-adequate diet of 2109 Kilocalories was 1.02 ± 0.21 USD per day, nearly twice the mean cost of a starchy staples diet at 0.54 ± 0.16 USD per day (Bai et al., 2021). This highlights a critical issue of the affordability of nutrient-adequate diets.

A review of Ghana's food environment, along with a market survey using observational macroscan approach on the cost of nutrient-adequate diets, have primarily focused on urban areas (Annan et al., 2022; Mockshell et al., 2022). Cost analysis studies on national food prices, including those conducted in Ghana, rely on national-level data (Bai et al., 2021; Masters et al., 2018) and often overlook the unique context of rural areas. These studies have also neglected the food accessibility challenges rural populations face; in the Eastern Region of Ghana, less than 10 percent of the population had access to markets regularly monitored by the World Food Programme (WFP), underscoring the accessibility issues in rural regions (World Food Programme, 2016). The WFP Vulnerability and Assessment Mapping (VAM) technical unit is responsible for closely monitoring markets for essential food commodities, providing crucial

data that informs the WFP response mapping and interventions. Unlike urban areas, which mostly rely on supermarkets and street vendors for food, rural areas depend on local markets, which are more variable in terms of food availability and cost (Ogum Alangea et al., 2018). Previous cross-sectional studies showed that more than 50% of calcium intake in rural children (2-5 years) came from the foods purchased outside the house in rural areas (Annan et al., 2022; Nti, 2008).

Overall, calcium is often overlooked in Ghanaian research. Few observational studies documented calcium intake levels across African countries, with Ghana having only two studies focusing on women of reproductive age (Kobati et al., 2012; Nti, 2008). It is essential to assess women's knowledge about calcium to inform the development of targeted policies. There are no studies in Ghana specifically evaluating calcium knowledge. In addition, investigating the cost of calcium-rich foods in rural Ghana will provide insights into the availability and affordability of non-dairy local foods that can sufficiently supply dietary calcium.

Inhibitors	Sources of inhibitors	Enhancers	Sources of enhancers
Oxalate	Beans, sweet potatoes,	Lactose	Milk
	okra	Casein proteins	
Phytate	Legumes, nuts, seeds	Vitamin D	Supplements, Sun
Palmitate	Palm oil	Nixtamalization	Corn soaked in calcium hydroxide

Table 2.1. Enhancers and inhibitors of calcium absorption

Author, publication year	Study setting	Micronutrients of concern	Micronutrient status	Study design/ sample size
<i>y</i> =			Deficiency (%)	
Wegmuller,	Rural	Iron ^a	8	Nationally
2020		Folate ^b	52.2	representative
		Vitamin A ^b	1.9	cross-sectional
		Vitamin B12 ^b	7.4	n=973
Ghana	National	Iron ^a	8.9	Cross-sectional
Micronutrient		Vitamin A ^b	1.5	stratified
Survey, 2017		Folate ^b	53.8	survey
		Vitamin B12 ^b	6.9	n=1053
Gernand, 2019	Rural	Iron ^a	12	Cross-sectional
		Copper ^b	7	n=98
		Vitamin A ^b	7	
		Zinc ^b	4	
			Dietary Intake (mean	
			± SD)	
Agbemafle,	Peri-urban			Cross-sectional
2016 °		Folate (µg/d)	119 ± 85	n=134
		Vitamin A (IU/d)	218 ± 37	
Kobati, 2012 d	Rural zones of:			Cross-sectional
	Coastal Savannah	Calcium (mg/d)	471 ± 323.9	n=168
	Guinea Savannah		395 ± 167.2	
Nti, 2008 ^e	Rural Manya Krobo	Calcium (mg/d)	595.30 ± 477	Mixed
		Vitamin B1	0.80 ± 0.3	methods study
		(mg/d)	0.60 ± 0.3	n=400
		Vitamin B2	10.80 ± 2.5	
		(mg/d)		

Table 2.2. Studies on micronutrient deficiencies among Ghanaian women of reproductive age

^b Deficiency cut-offs: folate <10 nmol/L; Vitamin A via retinol binding protein < 0.7 μ mol/L (Wegmuller et al. (2020) and Ghana Micronutrient Survey); Vitamin B12 < 148 pmol/L (Wegmuller et al. (2020)), < 150 pmol/L (Ghana micronutrient survey (2017)); Copper < 70 μ g/dL; Vitamin A via serum plasma retinol < 20 μ g/dL (Gernand et al. (2019)); Zinc serum plasma < 66 μ g/dL

^c Compared to recommended dietary allowance to define the intake deficiencies

^d Compared to the estimated average requirements to define the intake deficiencies

^e Compared to recommended nutrient intakes to define the intake deficiencies

^a Iron deficiency anemia was assessed.
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<u>Chapter 3. Calcium is Neglected in the Diets of Rural Ghanaian Women: Intake Levels,</u> <u>Knowledge, and Affordability in the Local Food Markets</u>

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Abstract

Calcium is crucial for bone health, but its deficiency is still common in low- and middle-income countries. In Ghana, there has been limited research on calcium intake. This study investigated the calcium intake levels among Ghanaian rural women, their sociodemographic predictors, top food contributors, knowledge about calcium, and the cost of top calcium-providing foods in markets. Firstly, a secondary quantitative analysis of recalls from 315 women in the Eastern Region was conducted. Predictors were assessed using a hierarchical mixed model, adjusting for body mass index and energy intake. Secondly, a qualitative study using focus group discussions assessed the knowledge of calcium among 47 women in another community of the Eastern Region. Finally, market assessments identified foods contributed to the most calcium at the lowest cost. The median [inter-quartile range] calcium intake was 602.7 [424.4, 886.7] mg/day. Most participants aged ≥ 25 (61.3%) and ≤ 24 years (73.3%) had calcium intake below recommended levels. Education level was negatively associated with calcium intake (p=0.01). The top food contributors to the total calcium intake for the sample were smoked fish (35.6%), banku (stiff porridge made with corn and cassava dough) (13.8%), and fried mackerel (6.9%). In the qualitative study, almost all women did not recognize the word calcium, yet they mentioned some of the important food sources correctly. Nutritional information was mainly acquired from the healthcare staff and schools. Additionally, cost-effective, top calcium-providing foods are available in the local markets. Greater emphasis on calcium is necessary in Ghanaian health policies and programs.

Key words: rural women, Ghana, dairy products, food environment, calcium, dietary intake

Introduction

Calcium is essential for maintaining bone health (Cormick & Belizan, 2019). Despite its importance, calcium deficiency remains prevalent around the world, especially in low-and middle-income countries (Balk et al., 2017; Shlisky et al., 2022). In 2011, nearly 90% of the 3.5 billion individuals at risk of calcium deficiency were located in Africa and Asia (Kumssa et al., 2015). Calcium deficiency can lead to serious health issues including osteoporosis and increased risk of bone fractures later in life (Matikainen et al., 2021).

Women of reproductive age (WRA) are particularly at risk of deficiencies due to their physiological demands for calcium. However, most African countries lack data on women's calcium intake levels (Balk et al., 2017; Shlisky et al., 2022). There are only a few older studies documenting calcium intake levels among Ghanaian WRA (Kobati et al., 2012; Nti, 2008). In addition, the absence of Ghana from a report on osteoporosis among African countries published by the International Osteoporosis Federation underscores the critical need for more data on calcium deficiency consequences (Atiase & Quarde, 2020).

Studies in other countries have reported green leafy vegetables, fish, cereals, and groundnuts as non-dairy sources of calcium in women's diets (Ignowski et al., 2023; Prentice et al., 1993). Other studies have also reported predictors of calcium intake, including sex, age, marital status, and education level (Islam et al., 2023; Muggaga et al., 2023). However, there remains a lack of similar research in Ghana on calcium intake levels, top food contributors to calcium intake, and intake predictors of calcium.

In Ghana, previous research has identified several factors contributing to the challenge of achieving nutrient adequacy, including limited knowledge, the high cost of foods, and restricted access to local food markets (Awuah et al., 2021; Masters et al., 2018; World Food Programme,

2016). Regarding the first factor, there is no published study specifically examining the knowledge of calcium in Ghana. Worldwide, however, studies have assessed the women's perception of calcium intake and its importance, mostly focusing on younger adults in highincome countries (Hagy et al., 2000; Holland & Moffat, 2017; Marcinow et al., 2017; Rouf et al., 2019; Zablah et al., 2004). In addition, the high cost of food is considered a barrier to achieving nutrient-adequate diets (Herforth et al., 2020; Masters et al., 2018; Novotny et al., 1999). The cost of a nutrient-adequate diet refers to the cost of food items required in a daily diet to meet the nutrient requirements (Masters et al., 2018). In Ghana, the cost of a nutrient-adequate diet almost doubled between mid-2010 and 2014, rising from 1 to 2 USD per day, which was mainly driven by the increased cost of foods rich in vitamin A and calcium. Available research on the cost of nutrient-adequate diets are conducted mostly in urban settings (Annan et al., 2022; Mockshell et al., 2022), overlooking the cost of foods in rural markets. There are no studies on the cost of calcium-rich foods in rural markets of Ghana. In rural Ghana, women's diets comprise a mix of household-produced foods and market-purchased items. It has been shown that home food production does not supply sufficient calcium (De Jager et al., 2018).

This was a 3-phased study aimed to (i) assess the calcium intake levels among rural WRA in Ghana; (ii) explore women's knowledge regarding calcium and its dietary sources, the perceived barriers to calcium intake, and source of nutritional information; and (iii) assess local markets to evaluate the cost of top contributors to calcium in the diets of rural women.

Key messages:

 Calcium intake levels of rural women in Eastern Region of Ghana were below the Harmonized Average Requirement levels.

- Smoked small fish (herring) and *banku* (stiff porridge made with corn and cassava dough) were the two top sources of calcium intake for rural women in Ghana.
- Although women did not recognize calcium by its name, they mentioned some of the food sources correctly.
- Least expensive top contributors to calcium in the diets of women were fish with its bones and milk powder.

Methods

This study was embedded in two other projects, using an explanatory sequential mixed-methods approach (Zoellner & Harris, 2017). Figure 1 shows the overall picture of the current study, which consisted of three phases:

- Phase 1: A quantitative secondary analysis of dietary calcium intake data from *LinkINg* Up: Women's Agripreneurship Sustainability and Scale-up Initiative project conducted in the Eastern Region of Ghana (registered at ClinicalTrials.gov, NCT03869853)
- Phase 2: A qualitative assessment of women's knowledge residing in the Eastern Region
 of Ghana and participating in the *Youth and rural women entrepreneurship* (URWE): *Creating and sustaining alternative livelihood options in Ghana* project
- Phase 3: Market assessments conducted in two popular local markets in the Eastern Region of Ghana.

The LinkINg Up and Youth and rural women entrepreneurship: Creating and sustaining alternative livelihood options in Ghana protocols were approved by the ethics committee of both McGill University and University of Ghana (Linking Up: McGill: 19-10-043, University of Ghana: ECBAS 035/18-19; URWE: McGill: 22-12-046, University of Ghana: ECH 137/22-23). All women provided written informed consent.

Study location

All phases of this study took place in the Eastern Region of Ghana, but in different communities. Phase1 was carried out in eight rural communities in three districts (A, B, C) between 2019 and 2021. Phase 2 was conducted in one rural community in district A in 2023. Phase 3 occurred in the main markets of two communities in district A in 2023. While this study included multiple phases carried out in neighboring communities, these communities are all located in the same region and share similar demographic characteristics (Ministry of Food and Agriculture, 2022). The Eastern Region, located in southeast Ghana, is the third largest out of the 16 regions (Ghana Health Services, 2024). The population in 2015 was 2,921,493 (10.7% of Ghana's overall population), with women accounting for 51% of the total adult population (Ghana Data Portal, 2024). The Eastern Region has tropical vegetation and experiences a rainfall pattern characterized by two peaks, resulting in distinct dry and wet seasons. Agriculture (mainly staple food crops), fishing, and animal sales are primary livelihoods of the population (Ghana Health Services, 2024).

Phase1: Quantitative study on calcium intake

LinkINg Up project and study participants

The LinkINg Up project was a quasi-experimental, nutrition-sensitive agricultural intervention involving a total of 330 women and 205 men, enrolled over two periods (2019-2020 and 2021-2022). Project details and inclusion criteria are described elsewhere (Abdu et al., 2022). Relevant data included dietary intake (three 24-hr dietary recalls, covering two weekdays and one weekend day), socio-demographic information (e.g., age, education, marital status), and anthropometric measurements.

All 330 women who participated in the baseline of both enrollment periods were initially included in the present secondary analysis. However, due to incomplete dietary data, 315 out of the initial cohort of 330 women were ultimately included in the final analysis.

Statistical analyses of Phase1

Calcium intake levels. The nutrient composition of Ghanaian food items in the 24-hr recalls of rural women was derived from a prior project's food composition dataset, based on local and international resources (Lartey et al., 2014). In cases where a food item did not exist in the dataset, the West African Food Composition Table was used (Vincent et al., 2020). Next, to account for both inter- and intra-individual variability in nutrient consumption, the Multiple Source Method (MSM) statistical modeling technique was used (Harttig et al., 2011). The MSM is a method for estimating usual dietary intake of nutrients for populations which accounts for the within- and between-person variabilities in intakes (Haubrock et al., 2011). The MSM results include the usual intake of each participant (accounted for the within-person variability) as well as the mean intake of the population (accounted for within- and between-person variability). To assess the adequacy of calcium intake among women, median calcium intakes (mg/d) of all participants were compared against the Harmonized Average Requirements (H-AR) (Allen et al., 2020). Median and inter-quartile ranges of calcium intakes were categorized and reported in two age groups as per the H-AR (18– to 24-year-old women, and \geq 25 years old women), and subsequently compared to the H-AR values corresponding to the age group. Although based on data from European and North American countries, it is suggested that these recommendations can be feasibly adopted by other countries until local estimates become available.

Potential predictors of calcium intake. Potential predictors were selected based on a combination of established literature and data-driven considerations. Previous studies have

identified some predictors of calcium intake, such as sex, ethnicity, marital status, and education level (Islam et al., 2023; Muggaga et al., 2023). In addition, other socio-demographic factorsage, wealth index, household size, community, and residential area- were included as potential predictors, considering the specific context and location of the research study. All potential predictors (age, education level, marital status, wealth index, ethnicity, household size, community, and residential district) were included as categorical variables in the final model, except for energy intake and body mass index (BMI). We categorized age into 5-year intervals to precisely capture variations in the calcium intake, as we assumed potential differences in intake levels and physical activity between, for example, women aged 25 years and those aged 35 years. Due to lack of existing studies confirming this hypothesis, we opted for smaller age groups to avoid generalizing the data by potentially aggregating diverse calcium intakes across various age ranges. Education level in our model was the highest level of formal education that women held, categorized into three categories of no formal education, primary level education, and secondary or higher education level. Marital status had two levels: being married and not being married. The household wealth index tertiles were created for the first component of a principal components analysis of 18 household assets, including improved water source, floor materials, wall materials, roof materials, toilet facility, cooking fuel, ownership of agricultural land, small livestock, non-mechanized farm equipment (i.e., hand tools), mechanized farm equipment (i.e., tractor), house or building, electricity, motorcycle, bicycle, cellphone, radio, television, and refrigerator. Ethnicity was divided into two categories: Krobo and other ethnicities including Ashanti, Dangme, Ewe, Ga, and Akan. Household size was included in the model as a categorical variable with nine categories. Each category represented the number of people living together in the same house, ranging from 1 to 13 individuals. To ensure sufficient degrees of

freedom, categories encompassing households with 9 to 13 members were combined into a single category. Our analysis demonstrated that varying the representation of household size— whether as a categorical or continuous variable, or with 13 or 9 distinct categories—did not alter the results. We retained household size in the model as 9 categories to estimate its effect size. Finally, the model included eight communities distributed across three districts in the Eastern Region of Ghana.

Using a hierarchical mixed model, the association between potential predictors and calcium intake was assessed while adjusting for BMI and energy intake. The Bonferroni correction was used for post-hoc analyses on only the significant variables to investigate differences in calcium intake amongst the subgroups. A statistical significance level of p < 0.05 was applied for all analyses. Data were analyzed using PROC MIXED in SAS (version 9.4) software package (SAS Institute Inc, 2023).

Top food contributors to dietary calcium. To identify top food contributors to calcium in the diets of women, all food items from every available recall were compiled into an Excel spreadsheet. The average number of grams consumed of each food item existing in the recalls was calculated. Then, using the calcium content of Ghanaian foods extracted from the food composition tables, the calcium per serving of food item consumed by the population was calculated. Finally, the percentage of contribution of each food item was calculated and sorted in descending order to find the top contributors to calcium intake in the diets. These top contributors guided the formulation of the next phases of the project.

Top food contributors to calcium in Ghanaian cuisine are typically consumed alongside other foods in a meal. To understand the common food combinations, a food atlas from Folson et al.

(2022) was used, exemplifying these patterns shown in Appendix 1. Although this atlas is primarily designed for adolescent girls in Accra, its relevance extends to older women due to the alignment of meal combinations with our dataset of recalls for adult women.

Phase2: Qualitative study on nutrition knowledge

URWE project and study participants

The URWE project aimed to diversify women's sources of income beyond *gari* (roasted cassava flour) production in the community. The inclusion criteria included (i) working in *gari* production, (ii) having residency in the community for at least 12 months, and (iii) being between 20 and 40 years old. The women were either entrepreneurs who owned processing facilities and farms, employing other women and men in *gari* processing, or small entrepreneurs who leased processing facilities but also hired staff in *gari* processing. All 100 women in the URWE project were invited to participate in the study, 47 agreed to take part in focus group discussions (FGDs).

Data collection process

Data collection took place from July 18th to August 25th, 2023. Trained field staff administered a brief demographic survey before the FGDs to collect information on age, education level, primary source of income, marital status, and the number of children residing in the household. Then, the FGDs were conducted in the local school setting, chosen to minimize distractions and increase confidentiality.

Food Cards Creation

Food cards were created to assess the knowledge of women on food sources of calcium. The Food-Based Dietary Guidelines of Ghana (Ministry of Food and Agriculture, 2023) served as the foundation for developing food cards and identifying local food items. Additional specifications were necessary to tailor the guidelines to the local dietary practices. Firstly, foods that were consumed locally in women's diets were selected using the guidance of a key informant – a local dietitian. Secondly, based on the Phase 1 findings, the top ten food contributors to calcium were incorporated into the set of cards based on their percentage of contribution to the total calcium intake. The food cards were printed four items per A4-size paper, cut, and laminated.

Focus group discussions

The FGD guide (Appendix 2) was initially prepared in English; the local team translated it into Krobo (the local language) and pilot tested it with six women who were not part of the URWE project but resided in the same community. Instead of referring to "calcium-rich foods," the term "good for bone" was used during the FGD to facilitate understanding. The phrase "good for bone" came from the women in the pilot group who had difficulty understanding the meaning of calcium. In addition, it was the closest term to calcium-rich foods for the women as there was not any known translation for calcium in their local language.

Each FGD lasted about one hour and included 6-7 participants seated in a circle-shaped arrangement (Lakshman et al., 2000). In addition to the participants, each session included the principal researcher, a facilitator, and a note taker. The principal researcher observed the participants closely, paying attention to their non-verbal reactions. An experienced female facilitator, proficient in the Krobo and from the neighbouring rural area, guided and facilitated the discussions. The note taker, a resident of the study village, documented the card sorting process by women, and promptly recorded participants' reactions and statements. After each FGD, the principal researcher, facilitator, and note taker held reflective discussions on-site,

analyzing the session and sharing insights from women's discussions. Women were given a bar of soap as a compensation for their voluntary participation.

Each FGD was given identical sets of food cards to assess participant's knowledge of the calcium content about the displayed foods. They discussed each card and reached a consensus on foods that are good for bones. This activity with food cards aimed to gain insight into how participants categorized items within their cultural context and to observe their discussions and reasoning during the sorting process (UNICEF, 2022).

After each FGD, an experienced field staff member completed verbatim transcription of recorded audios and translation into English. The principal researcher reviewed the English transcripts for clarity and completeness. If needed, iterative exchanges between the researcher and translator clarified unclear sections. Another native speaker independently verified the accuracy of the English translations for all the FGDs.

Qualitative analysis

The qualitative analysis was facilitated using MAXQDA 2024 software. Initially, codes were derived from the questions on the FGD guide (Appendix 2) with a deductive approach, with subsequent expansion through an inductive approach. Frequency was not a consideration during the coding process. Thematic analysis followed the six-step method by Clarke and Braun (2022), which involved familiarization with the data, generating initial codes, exploring and conducting themes, reviewing themes, determine significance of themes, and producing the report (Braun et al., 2022). Data saturation was reached when no new themes emerged from the responses (Hennink & Kaiser, 2022).

Phase 3: Market assessment of calcium food sources

A market survey about food sources of calcium in two rural communities was conducted at the same time as Phase 2. A list of frequently mentioned food markets was compiled based on women's responses to the market assessment question in the FGD. Two frequently mentioned rural food markets were visited by the principal researcher and research staff.

Data collection process

The field staff used a pre-prepared list of foods (top contributors to calcium intake identified in Phase 1) to purchase from vendors, previously unknown to them and selected based on convenience sampling, in each of the two markets. Each food item was collected from a different vendor. To calculate an accurate price per 100 g, foods were purchased and then weighed using a Seca scale (precision to 0.1 g). To minimize the bias in food price declaration by vendors, the principal researcher did not enter the market during the data collection conducted by the local staff.

Data analysis

The prices collected from the two markets were averaged. Then, the price of each food item was calculated for a 50-mg increment increase in calcium intake. Next, the quantity (g) of each food item needed for 50 mg increase in calcium was calculated and the extra energy introduced into the daily diet through this dietary calcium adjustment was assessed. Soups and stews, which were amongst the top contributors, could not be collected from the market as they were homemade. However, the price of their ingredients, such as *Kontomire* (cocoyam leaves), was collected.

Results

Phase1: Quantitative study of calcium intake

The baseline characteristics and nutrient intakes of participants are shown in Table 3.1. The women included in the analysis had an average age of 44.8 ± 13.3 years and were nearly evenly distributed across education levels and enrollment periods (2019-2020: 47.6%, 2021-2022: 52.4%). The median [inter-quartile range] intake of calcium was 602.7 [424.4, 886.7] mg/day. Among women who had primary education, 61.8% were members of farmer-based organizations (FBO) and 38.2% were non-members (p< 0.001). Among women with secondary education level of higher, 45.6% were FBO members and 54.4% were non-members (p< 0.001).

Women's calcium intake levels

The median [inter-quartile range] intake of calcium was 602.7 [424.4, 886.7] mg/day. The calcium intake levels of the women were compared to the recommended levels in each age group following the H-AR method. Over 70% of women 24 years old and younger had calcium intakes below the recommended levels of 860 mg/day for their age bracket. Likewise, 61.3% of women aged 25 years and above had lower calcium intakes than H-AR levels (Table 3.2). There was no significant difference in calcium intake levels of women by age category.

Among the tested sociodemographic predictors, only education level (p=0.01) demonstrated a significant association with calcium intake levels in the diets of rural Ghanaian women (Table 3.3). Household wealth index was marginally associated with calcium intake (p=0.05). Post-hoc analysis showed that individuals with primary education had a significantly higher mean calcium intake compared to those with secondary education or higher (least square mean \pm standard error: 734.0 \pm 39.5 vs 649.1 \pm 40.1 mg/d) (Table 3.4). Additionally, individuals in the low wealth index

tertile showed a tendency towards higher calcium intake compared to those in the high wealth index tertile (least square mean \pm standard error: 754.2 \pm 40.0 vs 662.5 \pm 42.5 mg/d). The community was considered as a random variable in the model and was tested for its significance. Roughly five percent of the total variability in the outcome was from differences among communities (variance community= 2117, variance of residuals= 40166, phenotypic variance= 42283). To determine the significance of this variance, model fit statistics were compared with and without the community variable using the Bayesian Information Criterion (BIC). The result showed a 2.8 % difference in BIC values before and after adding the community variable to the model, which is lower than the cut-off of 3. This indicates that the difference is not significant and provides little evidence for any real difference (Steel et al., 1997).

Top food contributors to calcium intake

The top ten food contributors to calcium in women's diets are shown in Table 3.5. *Banku*, with a low calcium content (25 mg per 100 g), ranked second in calcium contribution, due to the larger portion sizes consumed (nearly half a kg per day). Milk powder, a rich source of calcium (1100 mg/100 g), was only consumed in small quantities (mean intake of 15.5 g/day) and infrequently (in only 2.71 % (n=25) of the 921 dietary recalls). Palm nut soup and light (tomato-based) soup accounted for 6.6% and 3.2% of the total calcium in the dataset, respectively. All soups and stews were considered meatless in the local food composition table. Similar to *banku*, these soups are among the top contributors to calcium intake due to the large portion sizes consumed, averaging nearly 230 g per day. Similarly, two stews (*kontomire* and okra) were among the top contributors to dietary calcium. Despite containing more calcium per 100 g than the mentioned soups, their status as top contributors were due to their high daily consumption rates (Table 3.5).

The definitions of Ghanaian food items are represented in Appendix 3. The top contributors to calcium listed in the Table 3.5 are typically consumed as part of complete meals, accompanied by other food items such as fish or tubers which might have calcium themselves (example combinations are shown in Appendix 1).

Phase 2: Qualitative study on nutrition knowledge

Socio-demographic characteristics

A total of 47 women participated in the focus group discussions, with an average age of 34.6 ± 4.4 years. Among them, 58% had between 1 to 3 children, while the remaining participants had four or more children residing in the same household. Educational backgrounds varied; 48.6% had no formal education, 21.6% had completed primary schooling, and 29.8% had attained secondary education or higher. Although all of the women were involved in the *gari* industry, the primary source of income for the majority (64.8%) was *gari* processing, while 29.7% were engaged in farming, and the remaining participants were traders. Most women were married (86.1%) while 8.4% were single and 5.5% were divorced.

Women's knowledge about calcium and its importance

Of 47 women across all seven FGDs, only one woman named "calcium" and connected it to the bone health. She mentioned groundnuts as a source of calcium: "... *the groundnut in the soaked gari is good because it gives calcium*. so, *it's good for the bone*". Other respondents did not know the term calcium. They acknowledged that certain components in food help in bone healing when, for example, a friend had a broken leg.

Food sources perceived to be "good for bones"

Women faced difficulties in providing relevant explanations when categorizing foods as good for bone. Frequently, they either remained silent or offered reasons unrelated to calcium content or bone health, such as properties like aiding in constipation relief or deworming. However, among the answers related to bone health, three main themes emerged about the foods perceived to be beneficial for bone health: 1) foods that have bones, 2) foods that come from the cow, and 3) foods that give blood. Appendix 4 shows some food items that were not included in our food cards but mentioned by women as being perceived as calcium rich.

Theme 1: Foods that have bones

Participants consistently mentioned the beneficial effects of eating foods containing edible bones on human bone health. The method of cooking was not a concern for women, and they considered all types of fried, smoked, or powdered fish, and canned sardines, to be beneficial to human bones.

"The sardine is important because fish's bone ... is good for bone (FGD 3, Pos. 67)" "Powdered fish is good for the bone. Because it has a small bone which is[good] for bone (FGD 3, Pos. 185)"

Regarding meat, they noted that although the bones of goats, cows, and grasscutters (*Thryonomys swinderianus*) cannot typically be consumed, adding these bones to soups and consuming the bone marrow was seen as beneficial for bone health.

"When you eat grasscutter you have to eat with its bones so that it makes your bone stronger... there is something in its bone that makes our bone stronger. (FGD 3, Pos. 129-131)"

"Only bone of a cow is good for bone, and you can make soup with it. (FGD 3, Pos. 173)"

"Goat meat is also good, but you should eat it with the bones, so you shouldn't eat only the meat but eat the bones also because of something inside it (FGD 3, Pos. 189)"

Theme 2: Foods that come from the cow

Apart from the perceived benefits of fresh cow's milk, which some women mentioned unprompted, dried milk powder was seen as advantageous due to the fact the product originated from cows. One common brand was available in sachets or cans and was predominantly used by women in recipes for *gari* soaking (a local drink), certain porridges, or blended into their tea.

"The [local brand] also comes from the cow so it's good for bone (FGD 2, Pos. 163)" "I think [local brand] will be good for the bone because it [is] also milk and we get it from the cow so when we drink, it goes into our body and its good for bone. (FGD 3, Pos. 133)"

Theme 3: Foods that give blood

Women frequently perceived foods that give blood as being important for bone health, often describing it either as "it has iron inside" or as "it provides blood." The majority of women considered non-animal source foods to be the main providers of iron. Turkey berry (*Solanum torvum*) was the most frequently mentioned food perceived to be giving blood. Following closely behind were *kontomire* (cocoyam leaves) and groundnuts. Other foods believed to contain iron, although mentioned less frequently, included beans, oranges, mangoes, okra, tomatoes, plantains, cabbage, and Sobolo (a local herbal drink made using *Hibiscus* flowers).

"I can say okra is also good for the bone because it contains iron which is good for the bone (FGD 3, Pos. 96)"

"I say orange is good. when you take it after a meal, it gives something called iron [...] (FGD 3, Pos. 123)"

"Kontomire is good for bone, and it gives you blood also. If it gives you blood, then your body is strong (FGD4-revised, Pos. 93)" There were food cards of animal-source foods (goat meat, beef, canned sardine, egg, game meat, snail, and fish) cooked with different methods (fried and smoked). Among all the animal-source foods, women mentioned fish powder, eggs, and snails as good for bones because they have iron. No one mentioned meat as a source of iron.

"Powdered fish is very good for the bone because [...] it gives blood too (FGD 6, Pos. 228)"

"Egg gives blood and good for the bone (FGD4, Pos. 100)"

When questioned further about how they connected iron-rich foods to bone health, women consistently expressed the belief that if someone suffered a bone fracture, they lose a significant amount of blood, and thus they should consume foods that aid in replenishing blood:

"[...] because he will short blood and the turkey berries provide blood (FGD 1, Pos. 54)"

Or they mentioned building strength as in the mechanism.

"If it gives you blood then your body is strong (FGD4, Pos. 93)" Eating snail is taboo in the Krobo community and it is mostly used to apply to wounds as it helps the wound to heal faster. Although they perceived eating snail as beneficial to human bones, they refrained to consume it.

"For snails, I never tried it before, but I heard they say it's good for the bone. We Krobos don't eat but others eat, and the tribe that they eat they say it's good for the bone. (FGD4, Pos. 153)"

Moreover, some concerns were raised by some women regarding the oil, starch, or sugar content of certain food cards which can make them harmful to bones. In general, women believed that foods containing oil, sugar, or starch, "*make the person heavy*". Therefore, foods that do not contain these dietary components "... *will help him reduce in weight and for that matter he can step on the broken leg because he is no longer heavy (FGD 2, Pos. 195)*".

Women's source of nutritional information

Healthcare staff and schools were the most frequently mentioned sources of knowledge (Appendix 5). In all FGDs, there were several women who mentioned acquiring their knowledge of foods good for bones from healthcare professionals including doctors, mobile health workers, hospital staff, and even pharmacists: "*I learnt from the hospital, they educate me.*" In addition, several women indicated that they primarily obtained the recommendations while they were pregnant. "*I learnt from the hospital especially when you visit the hospital when pregnant (FGD 3, Pos. 219)*".

Schools emerged as second frequent source of information. Whether the women's own childhood institutions or their children's schools influenced their knowledge on calcium-rich foods and bone health. "*Sometimes our children also tell us after school (FGD 2, Pos. 200)*".

Women also mentioned learning about the foods good for bones from other people in different occasions such as conversation with a food vendor, at a social event, at work, or simply overheard. "For the beef, I learnt that from Koforidua slaughterhouse where I usually buy beef. So, when he adds bones I complain, and he advised me to eat it regularly. As I wake up very early to cook waakye [cooked rice and beans]. It will help me to stay strong. (FGD 1, Pos. 347)".

Barriers to consuming dietary calcium

The women explored their reasons for not consuming the top food contributors to calcium (using the cards for fish powder, canned sardines, local milk powder, okra, *kenkey* (a stiff porridge made of corn dough), smoked herring, *kontomire, banku* (stiff porridge made with corn and cassava dough), and fried fish). Women mentioned that they regularly consumed smoked small fish, *kontomire, banku*, and fried fish so there were no perceived barriers to consuming these

items. The reasons that emerged from their answers regarding the rest of the food cards presented to them are discussed next.

Not available in the market

A common explanation for the infrequent consumption of a calcium-rich food item (e.g., fish powder) was its limited availability in the local markets on a regular basis, as one of them mentioned, *"Powdered fish is what I don't eat regularly because it's not common here in the market (FGD 6, Pos. 309)"*

Price

The high price of some top contributors to calcium was frequently mentioned as a barrier to their consumption. Specifically, items such as fish powder, canned sardine, and local milk powder were often cited. These foods are perceived as expensive because of the portion size associated with the food item and level of satiety they provide to the family members. Less expensive alternatives, such as fried fish instead of canned sardines, were preferred.

"The rare powder fish is expensive than the normal smoked fish. That's why I don't eat (FGD4, Pos. 330)" "Sardine I eat but not regular because of the price which is 10 cedis. We have children so if you buy one it will not reach all of us, so I prefer buying fried fish instead of sardine (FGD 7, Pos. 313)"

"[local milk powder] are very expensive; price range from 9-12 (FGD5, Pos. 301)" Lack of nutritional knowledge

Some women reported that they did not perceive any benefits from consuming the fish powder, as one of them mentioned, *"For powdered fish, I don't know the importance of it that's why I don't eat it. (FGD 3, Pos. 227)"*

Perishability

Another barrier to the consumption of canned sardines was the necessity to use the entire contents of the can upon opening. There was a lack of refrigeration facilities in rural areas. As one participant noted, *'The sardine, when you open it, you have to use all, and that makes it hard to use since we don't have money (FGD 2, Pos. 250).'*

Personal preference

Other reasons that prevented women from consuming the top food contributors to calcium included their previous negative experiences, disliking the food because of its texture or taste, and having other established dietary habits. For example, a woman recalled a negative past experience which contributed to her aversion: "*I went to hospital when my child was sick, and they said I should buy sardine and apply the oil on the skin. When I applied it on the skin of my child, I smelled the smell and after that I couldn't eat it again. (FGD 7, Pos. 326)"* Some women mentioned disliking the fish powder and canned sardines "*because of the oil and smell (FGD4, Pos. 342)*." Other food items that some women did not like to consume included *kenkey*, okra, and canned sardines.

"For okra, it looks too stretchy [slimy], so I don't eat it regularly unless I cook it myself and decrease the stretchiness but even this way my family does not like it, so I don't cook it normally (FGD 3, Pos. 232)" "I don't like sardines because I don't like to eat [them]. If I eat, I will vomit (FGD 1, Pos. 334)"

There were other women who mentioned okra and *kenkey* created pain in their body when eaten, as one of them mentioned, "*Okra causes abdominal pains for me, so I don't eat at all. (FGD 7, Pos. 328)*"

Finally, some food items, milk powder for example, were not consumed due to established dietary habits within the local food culture. One participant explained, "*because for [local milk powder], I can only eat it with tea or gari soaking and I don't eat these (FGD 6, Pos. 331)*".

Women mentioned four different rural markets in Eastern Region of Ghana where they frequently purchased food. The most commonly recommended locations were two weekly food markets, one in their own community and the other one in an adjacent small town. This information was used to conduct the third phase of the study.

Phase 3: Market assessment

Table 3.6 shows the least-cost top contributors to calcium intake collected from two rural markets of the Eastern Region in Ghana. The least expensive top contributors to calcium were fish powder, smoked *amani* (smoked small fish or smoked herring), *kontomire* (cocoyam leaves), milk powder, okra, canned sardine, and fried mackerel, all costing less than 10 cents per 50 mg of calcium intake. For every additional 50 mg of calcium consumed from these top contributors, the cost of this addition was less than 10 cents in US dollars, and the portion sizes were reasonable. To increase calcium intake by 50 mg, the required portion sizes for each top contributor were: fish powder (1.5 g), smoked herring (3.5 g), milk powder (5.5 to 6 g), fried mackerel (14 g), and canned sardines (13 g). From the energy intake perspective, adding these portion sizes to the diets would result in an increase of fewer than 65 kcal.

The calculated amount based on 50-mg calcium intake increments for *kontomire* was 85 g. In practical terms, *kontomire* was often purchased and consumed in larger portion sizes, as it loses water during cooked. Collected data in this phase showed that a typical bunch of *kontomire* sold in the rural market weighed nearly 300 g.

In addition, Table 3.6 also shows the top food contributors to calcium intake that would not be suitable for dietary changes aimed at increasing daily calcium intake. For example, to achieve a 50-mg increase in calcium intake from *banku*, one would need to add 200 g of *banku* to the daily

diet. This would also add 216 kcal to the energy intake of women and cost 13 cents, which is almost four times the price of fish powder.

Discussion

In the Eastern Region of Ghana, the majority of rural women had calcium intake levels that were below the recommended levels. Among all the variables tested, only education level was associated, and household wealth was marginally associated with calcium intake. Small fish, especially when consumed whole (including bones), is rich in calcium. The bones of small fish are often soft enough to eat after being smoked, providing a significant calcium source. Although *banku* itself is not rich in calcium, its high consumption rates (almost half a kg per day) made it an important contributor. Certain soups and stews provided calcium in the women's diets because of the inclusion of vegetables like *kontomire* leaves, which contains moderate amounts of calcium, or because of their high daily consumption rates. Although almost all of the rural women did not recognize calcium by its name, they mentioned some of the important food sources correctly, learned from healthcare staff and schools. Identified perceived barriers to foods good for bones were lack of awareness, affordability, and availability. The market assessment highlighted the most affordable top food contributors to calcium for this Ghanaian population.

Similar to our findings, inadequate calcium consumption among rural WRA was reported by two previous Ghanaian studies (Kobati et al., 2012; Nti, 2008). The mean intakes of calcium were 395 ± 167 and 595 ± 477 mg/d, conducted in other rural areas of the Eastern Region of Ghana. Two recent reviews of studies in other African countries have also reported inadequate calcium intakes, ranging from mean values of 238 to 760 mg/d (Balk et al., 2017; Shlisky et al., 2022).
The last phase of this study suggested strategies to increase calcium intakes using the most locally affordable foods. Previous studies have proposed strategies for addressing low calcium intake at the household level. One strategy involves processing dried small fish foods into powder form to increase the amounts of nutrients like calcium in a given meal (Byrd et al., 2021). In Ghana, fish powder is commonly used as a condiment, and it is typically made from smoked small fish, incorporating all body parts, which makes it more nutrient-dense than fish fillets (Agyei-Mensah et al., 2023). A study showed that a 10-gram serving of fish powder provided 234 mg of calcium which covered more than 20% of calcium daily requirements of pregnant and lactating women (Byrd et al., 2021). Consuming fish with bones is particularly important for providing calcium, especially in populations with low dairy intake (Kawarazuka, 2010). In rats, the absorption of calcium from small fish bones is shown to be lower than that from skimmed milk (Larsen et al., 2000). Another proposed strategy is to add powdered eggshells to dishes as a condiment. This can provide 380 mg of calcium per g with a bioavailability comparable to calcium carbonate (almost 39%). Just one gram of powdered eggshells can meet half of a women's dietary requirements (Bartter et al., 2018). This strategy has been a topic of research since 2003; however, it was not widely practiced in Ghana, and the reasons for this are not well-documented in the literature (Rovenský et al., 2003). Another strategy used across Americas is nixtamalization, which involves soaking corn in calcium hydroxide. However, this practice is not common in African countries (Ekpa et al., 2019). This process is shown to increase the calcium content about 18 times in the whole grain and the endosperm and about 24 times in the germ of corn (Bressani et al., 2002). There have been no national programs on calcium intake in Ghana, likely due to the lack of

sufficient studies on calcium intake and consequences (Atiase & Quarde, 2020). Long-term low

levels of calcium intakes is associated with osteoporosis (Institute of Medicine, 2011). While osteoporosis rate in Ghana is still unknown, a previous review showed that the highest prevalence of osteoporosis in African countries almost 40%, based on a sample size of 2,989 people aged 18 to 95 years (95% CI: 22.3, 59.7) (Salari et al., 2021).

In the current study, socio-demographic predictors of calcium intake were examined. The analysis revealed that education levels was associated with calcium intake. Previous studies on the association between education with calcium intake are scarce in Ghanaian WRA. Results of studies conducted in other LMICs are also mixed and focused on pregnant and lactating women. A study among WRA in Uganda showed that education level of household head and spouse of women was not associated with calcium intake levels (Muggaga et al., 2023). Although not specific for calcium, education level of lactating women in Bangladesh was associated with diet quality- assessed using mean adequacy ratio. Lactating women who had secondary or higherlevel education had a higher MAR than those who had up to primary-level education (beta coefficient = 0.017, p = 0.038) (Islam et al., 2023). Another recent study in six Sub-Saharan African countries showed mixed results; however, an increase in women's education and household wealth was positively associated with minimum dietary diversity for women participated in studies from Kenya, Benue State in Nigeria, Senegal, and Tanzania (Janmohamed et al., 2024). Unexpectedly, in the present study, those who had primary education had higher calcium intakes compared to those who had secondary and higher education. A possible explanation could be that a higher proportion of women who had primary education than secondary or higher education were members of farmer-based organizations. This suggests that

these women may have been more exposed to nutrition education through these organizations (Colecraft et al., 2022).

Household wealth index was marginally associated with calcium intake among rural women in this study. There are no similar previous studies to our results. However, Agyei et al. (2021) showed that, among pregnant women in Northern Ghana, those who earned an income of equal to or more than 500 Cedis (US\$ 87) per month had higher dietary diversity scores compared to those who earned less. Dietary diversity score is considered to be reflective of nutrient adequacy which includes calcium (Agyei et al., 2021). Statistically, the marginal association between the wealth index and calcium intake levels observed in this study may be attributed to the insufficient sample size for this specific variable, which might have limited the ability to detect a significant result. A larger sample size could potentially yield more significant outcomes. Other potential predictors, including the age, household size, ethnicity, marital status, and residential district showed no association with calcium intake in the current study. The analysis considered whether variables as categorical or continuous would provide a better model fit using an overparametrized model (equivalent to orthogonal contrasts) (Green et al., 1999), and there was no improvement in model. All non-significant variables in the final model were kept as they did not to distort the results before and after excluding them from the model. Additionally, maintaining these variables in the model provided least-square means for each level, which can help estimate effect sizes for future research. Although age was not associated with calcium intake in the current study, a previous study indicated a significant negative association of Ugandan women's age with calcium intake only in harvesting season (Muggaga et al., 2023). Studies on household size and its effect on nutrient adequacy and intra-household food distribution have been conducted in rural Ethiopia and South Asia, with mixed results (Coates et

al., 2018; Harris-Fry et al., 2017). In detail, Coates et al. (2018) mentioned that adult women and children experienced nutrient inequities, especially for iron, rather than for energy or protein. In the systematic review by Harris-Fry et al. (2017), household size affected the participants' food intake but did not influence their food allocation patterns within the household. On the other hand, other studies in this review found that in nuclear households, where women typically bear the responsibility of feeding everyone, they receive comparatively less food, but in joint households, where extended family members reside together, including the mother-in-law who often manages food planning and distribution, women tend to receive more food resources (Harris-Fry et al., 2017).

The top food contributors to calcium intakes in the rural women's diets were smoked herring and *banku*. Smoked herring, despite being consumed in smaller quantities (31 g per day), was the top contributor due to its high calcium content (1481 mg per 100 g). Smoked herring, classified as smoked small fish, is commonly consumed with bones in poor Ghanaian households (Agyei-Mensah et al., 2023). Prior research has reported the calcium content in other African small fish species, including sardines and anchovies, and noted higher calcium levels when these fish are eaten with their bones (Aakre et al., 2020). That study found that whole sardines provided 716 \pm 200 mg of calcium per 100 g, while sardine fillets contained 309 \pm 118 mg/100 g. Similar findings were observed for anchovies, with and without bones, providing 535 \pm 56 and 211 \pm 34 mg/100g, respectively.

Banku, with a low calcium content (25 mg per 100 g), ranked second in calcium contribution, due to the larger portion sizes consumed (nearly half a kg per day). The results regarding *banku*

were unexpected. *Banku*, a staple food in Ghana, has not been studied for its calcium contribution to the diet.

Stews and soups were also identified as top food contributors to calcium intake in this study. In the local food composition table, all stews and soups were considered meatless. Therefore, the calcium content in these dishes predominantly comes from widely consumed vegetables in rural Ghana, such as *kontomire* (Nyadanu & Lowor, 2014). Additionally, these foods ranked high in calcium contribution due to their substantial consumption, averaging nearly 250 g per day. Among the top calcium-contributing stews and soups, *kontomire* stew had the highest calcium content at 67 mg per 100 g.

All but one woman were unable to recognize calcium by name, despite acquiring their knowledge about foods good for bones from formal sources, such as healthcare centers and schools. No previous studies among WRA in Ghana reported comparable results. Among students in Accra, online resources were the most common source of nutrition information although the healthcare professionals were perceived to be a more reliable source by this younger population residing in a city in Ghana (Quaidoo et al., 2018). There are a few other studies reporting the sources of nutritional information among other age groups in different countries. In South Africa, for instance, source of knowledge regarding calcium intake among white adolescent girls were teachers and parents (Chemaly et al., 2004). In Bangladesh, researchers assessed the sources of knowledge regarding the importance of calcium among undergraduates and found their teachers and textbooks to be main sources (Uddin et al., 2013). In Vietnam, mothers with low-income levels showed friends, physicians, and the media were the common sources of nutrition information regarding calcium's importance (Reed et al., 1998). In the US, the nutritional information was mostly learned from schoolteachers, parents, health

professionals, food labels, and the media among immigrant adults and adolescents (Tiedje et al., 2014).

Women in the study perceived iron-rich foods, mentioned as "foods that give blood", as beneficial for the human bone health. Discussing iron in response to questions about bone health and calcium likely stems from previous interventions and educational programs focused on eradicating iron deficiency anemia in rural Ghana (FAO & IFPRI, 2021). Studies have largely neglected assessing the knowledge of calcium and calcium-rich foods in Ghana. The term "blood-giving foods" has been frequently mentioned in studies assessing participants' perceptions about iron. Examples of foods that Ghanaian participants mentioned in these studies include eggs and smoked fish (Dalaba et al., 2021), small fish eaten whole (Agyei-Mensah et al., 2023), kontomire and turkey berry (Agbemafle et al., 2016; FAO & IFPRI, 2021) as well as indigenous vegetables (Atuna et al., 2022). Consistent with previous studies, in the current study, turkey berry and *kontomire* were often mentioned as sources of iron, rather than meat. The study also showed that rural women primarily gained their nutritional information from healthcare staff and schools. Similar results have been found in other nutritional knowledge assessment studies conducted in different countries. For instance, Reed et al. (1998) reported that friends, physicians, and the media were the main sources of nutritional information among women in Vietnam (Reed et al., 1998). Quaidoo et al. (2018) showed that among young adults in Accra, online resources were the most common source of nutrition information, but healthcare professionals were perceived to be the most reliable source (86.5%).

Nutrition knowledge does not always lead to improved diet quality. For instance, Dalaba et al. (2021) observed that although pregnant women in northern Ghana were aware that eggs and meat were rich in iron, they did not consume them regularly due to a lack of money. Other factors like cost of foods, availability in markets, and cultural beliefs also impacted dietary choices (Agbemafle et al., 2016). In the second phase of this study, women perceived fish powder as expensive and not readily available in the markets. This belief was supported by the results of Phase 1, where fish powder was not among the top food contributors because of its low consumption among women. The market assessment showed that it cost three cents (on average) and required only 1.5 g of fish powder to increase calcium intake by 50 mg in this population. Therefore, a small adjustment to incorporate fish powder into meals could help meet the calcium requirements in rural families due to its high calcium density. The accuracy of women's perception that fish powder was expensive can be assessed in future studies. Additionally, the lack of knowledge about the benefits of fish powder, as mentioned in FGDs, may contribute to its irregular consumption. Canned sardines emerged as another top contributor to calcium for rural women, despite barriers such as taste, texture, and perceived high cost. Each 100 g of sardines (priced at US\$ 0.54 per 100 g in the current study, Appendix 6) with bones can provide 716 ± 200 mg of calcium, covering almost 72% of recommended nutrient intake for adult women (Aakre et al., 2020).

The cost of a nutrient-adequate diet in Ghana increased from almost US\$ 1 to 2 between mid-2010 and 2014, mainly due to the expense of vitamin A- and calcium- rich foods (Masters et al., 2018). The current study found the least-cost calcium-dense items available on two rural markets in the Eastern Region included smoked small fish. A recent meta-analysis confirmed that herring, sardine, and anchovy were the least-expensive nutritious portion of fish in Ghana

(Robinson et al., 2022). In the meta-analysis, a nutritious portion of fish was defined as the cost of a portion of fish needed to meet 33% nutrient adequacy across six micronutrients, including calcium. The analysis also calculated the additional cost of adding a 100-gram portion of fish to an energy-sufficient diet of staple foods, which was about US\$ 0.20 in Ghana. In contrast, the current study found the local prices of smoked herring, canned sardines, and cooked anchovies to be US\$ 0.89, 0.54, and 0.81, respectively. This price discrepancy may be due to differences in calculation methods: the present study averaged prices collected directly from the markets, while the previous meta-analysis used median prices calculated from the country-level case studies. In addition, the prices in the current study are for cooked food items rather than raw ingredients used in the meta-analysis.

This study has some limitations that need to be considered. First, the first phase of the study did not assess other potential sources of calcium intake such as water and insects, which could be important sources for Ghanaian rural women (Anankware et al., 2016; Cormick et al., 2020). Second, diets contain antinutritive compounds that hinder calcium absorption. Therefore, dietary recommendations should account for these interactions in absorption in the gut, as Ghanaian women regularly consume palmitate (in palm oil), phytate (in legumes) and oxalate (in beans and okra) in the diets. Third, the harmonized recommended levels are designed for global use and might not reflect the specific amounts of calcium requirements in Ghana. However, Allen et al. (2020) suggested that these recommendations, while derived from European and North American countries, could be adopted by other countries until local estimates become available. Fourth, the limitations of collecting data through 24-hr dietary recalls, which can bring recall bias, should be acknowledged. Fifth, the women in the second phase of the study (URWE project) were younger than those in the first phase (LinkINg Up project). However, most demographic characteristics of

women in both phases and the markets they use are similar, and they were all located in the same region of Ghana. Sixth, in the second phase, choosing "good for bone" as an alternative term for calcium-rich foods might not be the most accurate term. However, women in the pilot group and local research staff suggested this phrase to enhance the understanding of "calcium-rich". Also, the results showed that, except for one woman, there was no familiarity with the term "calcium" and no translation for it in local language. Seventh, there was a language barrier in the second phase which might have affected the data collection process. Despite the second phase being analyzed by a single researcher, verbatim codes, peer debriefing, and participant details (following Cochrane guidelines (Hannes et al., 2011)) were employed to enhance the credibility and transferability of this research. Finally, the market assessment was conducted at one point in one season, which might not capture the availability and cost of food across all seasons. Seasonal fluctuations mostly affect the availability of fruits and vegetables (De Jager et al., 2023). It is also noteworthy that the nutrient content in fish fillet can vary throughout the year due to seasonal changes in their feed, yet more research is needed regarding the effect of seasons on fish bone nutrient content (Hasselberg et al., 2020).

Conclusion

The majority of rural Ghanaian women had calcium intakes lower than the recommended levels; this deficiency is overlooked by current policies. Women's education level was a predictor of their calcium intake, with higher education level being associated with lower calcium intake. Among various affordable calcium-rich foods that were identified in rural markets, smoked herring and fish powder seemed to be the best culturally accepted options. However, women in focus group discussions did not consume fish powder regularly, either because of their low awareness of its benefits, limited availability in markets, or perceptions of it being expensive.

Future interventions could focus on healthcare staff and schools to increase the population's knowledge of calcium, which were frequently mentioned as key sources of nutritional knowledge in this population.

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Variables	N (%) or mean ± SD or median [IQR]
Age groups (y) ^b	
≤ 24	15 (4.8)
25-30	23 (7.4)
31-35	34 (10.9)
36-40	43 (13.8)
41-45	37 (11.9)
46-50	49 (15.7)
51-55	35 (11.2)
56-60	26 (8.3)
61-65	27 (8.6)
66-70	10 (3.2)
71-75	5 (1.6)
76-80	6 (1.9)
81-85	2 (0.6)
Body mass index (kg/m^2)	25.3 ± 6.2
Household size (#)	5.2 ± 2.0
Ethnicity	
Krobo	279 (88.6)
Others ^c	36 (11.4)
Education level completed	
None	99 (31.4)
Primary	102 (32.4)
Secondary and higher	114 (36.2)
Marital status ^b	
Married	234 (75.0)
Not married	78 (25.0)
Household wealth index ^d	
Low	103 (32.7)
Middle	103 (32.7)
High	103 (32.7)
District	
Yilo Krobo	143 (45.4)
Lower Manya Krobo	87 (27.6)
Upper Manya Krobo	84 (26.7)
Farmer-based organization	
Member	163 (51.7)
Non-member	152 (48.3)
Median macronutrient intake ^e	
Energy (kcal/d) ^f	1886.1 [1442.2, 2508.0]
Protein (g/day)	61.3 [46.4, 84.6]
Fat (g/day)	58.3 [40.7, 79.8]
Carbohydrate (g/day)	283.7 [225.9, 377.9]

Table 3.1. Descriptive statistics of rural Ghanaian women farmers

SD: standard deviation; IQR: inter-quartile range

Rural Ghanaian women farmers are those who participated in the LinkINg Up project in Phase1. bn=312

^c Other groups of ethnicities: Ashanti, Dangme, Ewe, Ga, Akan

^d n=309. Wealth index tertiles: the tertiles for the first component of a principal components analysis of 18 household assets (improved water source, floor materials, wall materials, roof materials, toilet facility, cooking fuel, ownership of agricultural land, small livestock, non-mechanized farm equipment (i.e., hand tools), mechanized farm equipment (i.e., tractor), house or building, electricity, motorcycle,

bicycle, cellphone, radio, television, and refrigerator).

^e Usual intake was calculated using Multiple Source Method (Harttig et al., 2011), to account for interand intra-individual variability among 24-hr recalls. 92.4 % of the women had three and 7.6 % had two days of 24-hr dietary recalls. Median and inter-quartile ranges were reported.

^f Energy: 1 kcal = 4.184 KJ

Table 3.2. Calcium intake levels of rural v	women in the	Eastern Region of	Ghana compared to
the recommended levels			

Age,	n	Intake per day,	H-AR,	below H-AR,	Equal or above
у		median (IQR) mg/d	mg/d	n (%)	H-AR,
					n (%)
18-24	15	622.7 (519.6, 887.4)	860	11 (73.3)	4 (26.7)
25 and above	297	598.6 (419.9, 883.1)	750	182 (61.3)	115 (38.7)

There was no significant difference in calcium intake between the two age groups. H-AR: harmonized average requirements (Allen et al.,2020); IQR: inter-quartile range

Effect	Categories	Estimate	Standard Error	P value
Age (y)	≤ 24	659.3	65.0	
	25-30	774.1	56.5	
	31-35	694.1	47.9	
	36-40	729.7	45.9	
	41-45	649.9	48.8	0.43
	46-50	705.2	43.1	
	51-55	717.8	47.8	
	56-60	698.8	51.1	
	61-65	605.8	51.1	
	66-70	664.1	71.5	
	71-75	728.1	98.1	
	76-80	753.4	91.6	
	81-85 (Ref.)	740.0	149.9	
Household size (# of members)	1	746.5	93.5	0.34
	2	778.3	54.4	
	3	729.4	48.2	
	4	692.6	43.6	
	5	644.9	42.7	
	6	665.4	42.7	
	7	678.8	46.6	
	8	731.0	58.1	
	9 and above (Ref.)	647.2	62.0	
District	Lower Manya Krobo	667.7	65.3	0.68
	Upper Manya Krobo	707.1	50.2	
	Yilo Krobo (Ref.)	729.9	37.7	
Education level	None	721.6	39.5	0.02
	Primary	734.0	39.5	
	Secondary or higher (Ref.)	649.1	40.1	
Ethnicity	Krobo	717.1	30.9	0.44
2	Others (Ref.)	686.0	48.6	
Household wealth index tertile	Low	754.2	40.0	0.05

Table 3.3. Potential predictors of calcium intake with their least square means (mg/d) in the final model

	Middle	688.0	39.0	
	High (Ref.)	662.5	42.5	
Marital status	Married	714.3	37.8	0.41
	Not married	699 0	20.0	
	(Ref.)	088.9	39.0	

Ref.: reference group

A hierarchical mixed model was used, adjusting for body mass index and energy intake.

P values were for regression of each predictor on the outcome (calcium intake)

Highest level of education: none, primary, secondary & higher.

Household wealth index tertiles: the tertiles for the first component of a principal components analysis of 18 household assets (improved water source, floor materials, wall materials, roof materials, toilet facility, cooking fuel, ownership of agricultural land, small livestock, non-mechanized farm equipment (i.e., hand tools), mechanized farm equipment (i.e., tractor), house or building, electricity, motorcycle, bicycle, cellphone, radio, television, and refrigerator).

Ethnicity: Krobo (n=276), Others (n=36): including Ashanti, Dangme, Ewe, Ga, Akan

Districts where women recruited: Yilo Krobo, Upper Manya Krobo, Lower Manya Krobo.

Marital status: married, not married

Predictor	Groups	Versus	Estimate	Standard error	Adjusted p value
Education	None	Primary	-12.4	31.0	1.00
level	None	Secondary or higher	72.5	33.6	0.09
	Primary	Secondary or higher	84.9	30.9	0.02
Household	Low	Middle	66.2	32.7	0.13
wealth index	Low	High	91.6	39.5	0.06
tertiles	Middle	High	25.4	31.9	1.00

Table 3.4. Post-hoc analysis for potential predictors of calcium intake (mg/d) among women in rural Ghana

A hierarchical mixed model was used to find the potential predictors of calcium intake levels among rural women, adjusting for body mass index and energy intake. Bonferroni correction was used as the post-hoc analysis method to adjust for multiple comparison issues.

Contributor	Mean intake	Calcium ^b ,	Frequency ^c	Percentage of
	per day ^a , g	mg/100g		contribution ^d
Smoked herring ^e	30.7	1481	511	35.7
Banku ^f	445.7	25	809	13.8
Fried mackerel	38.7	360	323	6.9
Palm nut soup	237.4	38	480	6.6
<i>Kontomire</i> stew, no meat ^g	281.4	67	193	5.6
Light soup, no meat ^h	234.7	29	307	3.2
Fufu ⁱ	341.4	10	583	3.1
Okra stew, no meat	213.4	48	134	2.1
Kenkey Ga ^j	338.8	25	152	2.0
Cooked anchovies	25.5	232	196	1.8

Table 3.5. The top ten food contributors to dietary calcium intakes among rural women in Ghana

^a Mean g of food items consumed by the whole population in the dataset of all recalls collected from women

^b Mg of calcium per 100 g of each food item, according to the local food composition table.

^c Frequency of each food item in a dataset of 921 recalls including all days and meals

^d Percentage of each food's contribution to the total calcium intake, based on data from all recalls over all days for 315 women.

^e*Amani* is the local name for African herring.

^f A stiff porridge made of a mix of corn and cassava

^g Cocoyam leaves stew

^h A soup made of tomatoes, onions, garlic, ginger

ⁱ A stiff porridge made of cassava and plantain

^j A stiff porridge made of corn dough

	Price (USD) ^a	Amount (g) ^b	Energy (Kcal) °
Smoked herring	0.03	3.5	13
Fish powder	0.03	1.5	5
Kontomire ^d	0.03	85	30
Local milk powder Brand 2 ^e	0.05	6	2
Fresh okra	0.06	77	23
Canned sardines	0.07	13	27
Fried mackerel	0.08	14	65
Local milk powder Brand 1 ^e	0.08	5.5	23
Banku ^f	0.13	200	216
Kenkey Ga ^g	0.13	221	274
Cooked anchovies	0.17	21	45
Fufu ^h	0.41	500	630

Table 3.6. The least-cost top food contributors for increasing calcium intake by 50 mg increments in the diets of rural Ghanaian women

^a The average prices of for two food markets in Eastern Region of Ghana. ^b Grams of food items needed to increase the intake of calcium by 50 mg ^c Energy intake that will be added to the diet when adding 50 mg of calcium

^d Cocoyam leaves

^e Two local brands of milk powder were tested. Dairy products including milk and yoghurt could not be found on neither of markets.

^f A stiff porridge made of a mix of corn and cassava

^g A stiff porridge made of corn dough

^h A stiff porridge made of cassava and plantain

Figure 1. Outline of the study: An Explanatory Sequential Mixed-Methods Approach					
Phases	Research questions	Results	Study design		
Quantitative	What is the intake level of calcium among women? What predicts their intake level? What foods are mostly providing calcium in their current diets?	Lower than recommended level for majority of women in each age group Only education Smoked herring, Banku, fried mackerel, kontomire stew, light soup	Cross-sectional (n=315)		
		$\mathbf{\hat{\Gamma}}$			
Qualitative	What women know about calcium and its food sources? Where do they get their information from? What are the barriers to eating foods providing a sufficient amount of calcium?	Out of 47 women, only one recognized the calcium. Foods with bone, cow-derived foods, and blood-giving foods were mentioned being good for human bones Healthcare staff and schools Availability in local market, price, lack of nutritional knowledge, perishability, personal preference	Focus group discussions (n=7)		
		\mathbf{V}			
Market	What foods are available and affordable in local markets?	Fish powder, smoked herring, milk powder, fried mackerel, canned sardines	Market survey		
$\mathbf{\nabla}$					
There is an inadequate intake, a limited knowledge, and certain resolvable barriers among rural Ghanaian women. The overall picture suggests a critical need for further implementation research, and policy and program development in Ghana, to address the risk of calcium deficiency-related health issues later in life. These may include a wide range of policy actions that (i) promote fortification of sachet water or other vehicles, (ii) expand entomophagy, (iii) strengthen nutrition education through the schools and health services, (iv) integrate calcium supplements or top calcium-providing food options into social protection programs such as school feeding initiatives.					

Chapter 4. Discussion

This thesis built on existing literature by assessing calcium intake levels among in rural Ghana, with a focus on various aspects of the calcium landscape in this population. It introduced a new perspective by looking at the calcium as an essential micronutrient which has been neglected in policies and programs for rural Ghana. This research adopted a three-phased approach to provide a comprehensive understanding of the issue. The first phase assessed the calcium intake levels quantitatively and explored the predictors of intake and the top contributors to calcium in women's diets. The second phase complemented these findings by conducting a qualitative study seeking women's knowledge on calcium and its food sources to understand what the population knew about this essential nutrient. The third and last phase assessed the local markets and identified food products that would provide the most calcium for the least cost. Micronutrient deficiencies are significant public health issues, affecting almost one-third of individuals worldwide (Han et al., 2022). These deficiencies disproportionately impact vulnerable groups, particularly WRA and children under five years. While MNDs cannot be completely eradicated, they can be reduced to acceptable levels (Underwood, 1999). In Ghana, iron deficiency anemia has been a persistent issue among women for several years (University of Ghana et al., 2017). Although its prevalence is declining, it has yet to reach the targets set by the Sustainable Development Goals (United Nations Ghana, 2022). To combat iron deficiency, the government has implemented several measures, including the fortification of wheat, and supplementation (e.g., Girl's Iron and Folic Acid Tablets Supplementation programme). The government also made efforts to increase the awareness among women during prenatal care, aiming to prevent MND not only during pregnancy and lactation, but also in their infants and young children (e.g., the four-star diet counselling package). In addition to iron, the government

has addressed iodine deficiency through salt fortification (Nyumuah et al., 2012). Vitamin A deficiency, another common MND, has been better managed thanks to fortification of vegetable oil (Nyumuah et al., 2012). However, other micronutrients, such as calcium, have not yet been adequately addressed by the government.

There are strategies that can enhance calcium intake, such as adding powdered eggshells to children's foods right before the consumption. However, these studies have received little attention by other researchers, as the most recent one was conducted in 2021, and no further studies have continued in this direction. Adding grounded eggshell to food is shown to be safe and effective at the household level. Eggshells contain 380 mg calcium per gram which could provide 50% of an adult female's daily requirements (Bartter et al., 2018). Another study showed that a 10-gram serving of powdered small fish with bones provided more than 20% of calcium daily recommendation intakes in pregnant and lactating women (Byrd et al., 2021). The current study also identified the fish powder as one of the top contributors to calcium intake in rural Ghanaian WRA.

The government has yet to address calcium deficiency, likely in part due to limited data in the existing literature on the calcium landscape in Ghana. The current study showed that the calcium intake among rural women was lower than the recommended levels which can be concerning as calcium deficiency is associated with reduced bone mineralization and increased risk of fracture and osteoporosis later in life (Matikainen et al., 2021). However, more comprehensive research is needed on calcium intake levels, as calcium may have uncommon non-food sources in this population, such as soil (geophagy), insects (entomophagy), and water, which are not captured in 24-h dietary recall assessments.

Geophagy is the purposive intake of soil-like materials such as clay and it is more commonly observed in children, pregnant women, malnourished individuals, and among rural residents compared to urban ones (Kambunga et al., 2019). In Ghana, the prevalence of geophagy among WRA was reported to be 28% in 2013. Among pregnant women, it was about 46% in 2017, with an average intake of nearly 70 grams per day (Arhin & Zango, 2017; Tayie et al., 2013). However, none of the few previous nutrition studies have considered geophagy when assessing calcium intake.

In addition, entomophagy has been a traditional and cost-efficient dietary practice in West Africa which provides high amounts of protein and calcium and with a lower amount of fat compared to meat (Anankware et al., 2014). Entomophagy is not typically asked during 24-h dietary recall data collection. In Ghana, in a national survey of 2000 individuals, almost one-third reported entomophagy, the most common insects used being palm weevil larva (Rhynchophorus phoenicis Fabricius known as Akokono) and termites (Anankware et al., 2016). Termites and grasshoppers are rich in minerals, such as calcium, although their bioavailability is not well-studied yet (Kim et al., 2019).

Specifically for calcium, water sources should be considered when evaluating calcium intake, as a secondary analysis indicated that calcium-fortified water in LMICs could reduce the prevalence of calcium deficiency without exceeding the tolerable upper levels (Cormick et al., 2022). In suburbs of Accra, water has been found to contain calcium concentrations ranging from 14.4 to 43.2 mg/L (Gyamfi et al., 2012). However, in rural Ghana, sachet water is a primary source of drinking water (Moulds et al., 2022). The use of sachet water in rural areas of the Eastern Region began in the late 1990s, and between 2010 and 2017, its consumption rose from 3.8% to 17.4% of households largely due to intermittent public water supply shortages. As of 2022, sachet

water, which contains 500 ml of water sealed in plastic bags by machines, was consumed by 63% of Ghanaian households, with an average daily consumption of 0.97 liters per person (Wardrop et al., 2017). Sachet water is popular due to their ease of production for vendors, affordability (with a median price of \$0.05 per liter compared to \$0.25 per liter for bottled water), lightweight, and durability for consumers. While some sachet water is sold without clear information about its origin or quality, others are produced by major brands in Ghana (Moulds et al., 2022). Therefore, fortifying water could be considered an effective mass fortification strategy in Ghana.

Despite a few nutritional studies on calcium intake levels, Ghana still lacks a precise estimate of osteoporosis prevalence. A global meta-analysis found that the worldwide prevalence of osteoporosis was 18.3 % (95% CI: 16.2,20.7), with Africa having the highest prevalence at 39.5% (95% CI: 22.3,59.7) (Salari et al., 2021). However, these data do not specifically address Ghana. Other Sub-Saharan African countries, like The Gambia, Nigeria, Kenya, and Cameroon, have some research on osteoporosis prevalence, though it remains limited. For instance, the prevalence of osteoporosis in women over 60 years was reported as high as 65.8% in Nigeria (Atiase & Quarde, 2020).

Whenever calcium is discussed, it is essential to mention vitamin D as a critical factor, as its serum levels directly impact calcium absorption (Khazai et al., 2008). Calcium transport in the intestines, kidneys, and bones is tightly regulated by three hormones, one of which is 1,25dihydroxyvitamin D-3, an active metabolite of vitamin D (Yu & Sharma, 2023). Unfortunately, there are few studies with mixed results on dietary vitamin D intake and blood vitamin D status among the Ghanaian population. A meta-analysis estimated that approximately 20% of people in Africa have inadequate serum 25(OH)D concentrations using severe deficiency cut-off of 30
nmol/L. In this meta-analysis, only two studies from Ghana were included, showing a mean vitamin D status of 74.1 nmol/L, above the severe deficiency threshold (Mogire et al., 2020). However, another study reported a mean vitamin D deficiency prevalence of 43.6% across different regions of Ghana, based on a cut-off of 20 ng/mL, which indicates deficiency (Sakyi et al., 2021). Another study of pregnant women in Volta region of Ghana found that 81.7% had vitamin D deficiency, defined as serum 25(OH)D levels of 20 ng/mL or lower (Fondjo et al., 2021). Future research could concurrently explore vitamin D status and calcium intake levels in the Ghanaian population. These studies would be helpful in developing tailored interventions aimed at at-risk groups, such as women.

This thesis adopted a comprehensive approach by assessing not only calcium intake levels but also women's knowledge about calcium and the cost of calcium-providing foods in rural Ghana. This holistic perspective was informed by previous studies, which identified several contributing factors to achieving nutrient adequacy, including limited knowledge, high food costs, and restricted access to local food markets (Awuah et al., 2021; Masters et al., 2018; World Food Programme, 2016). By integrating these elements, the thesis offers a well-rounded understanding of the calcium situation in the region.

Nutritional knowledge of the population regarding micronutrients has received limited attention in previous research in Ghana. While few studies have examined the population's knowledge regarding iron and vitamin A deficiencies (Awuah et al., 2021; Omari et al., 2017), there has been a gap in assessing the knowledge about calcium and calcium-rich foods. Evaluating the population's perception of nutrients and foods provides insights into the depth of participants' perspectives, though such findings may not be generalizable to the entire population (Patton, 2015). Qualitative studies that explore these perceptions ensure that the results are grounded in

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real-world experiences. This study highlighted the limited knowledge among women regarding calcium and its importance, which can guide future interventions by identifying key areas for emphasis. Additionally, the study identified the sources of nutritional information, providing insights into where to focus educational efforts.

Furthermore, previous research has shown that rural Ghanaian households are unable to meet the calcium needs solely through home-produced foods as outlined by Ghanaian food-based dietary guidelines. Along with home-produced foods, they depend on market foods to satisfy their calcium requirements (De Jager et al., 2018; Nti, 2008). Unlike high-income countries, where dairy products are the primary source of calcium intake, LMICs rely on alternative sources of calcium (Bourassa et al., 2022). This study identified these sources in the Ghanaian local markets.

Overall, Ghana is transitioning from a high prevalence of communicable diseases to an increasing burden of non-communicable diseases, driven by rising life expectancy. This shift underscores the need to proactively address emerging public health issues, such as osteoporosis and bone fractures among women, which are linked to inadequate calcium intake. The overall picture suggests a critical need for further implementation research, and policy and program development in Ghana, to address the risk of calcium deficiency-related health issues later in life. These may include a wide range of policy actions that (i) promote fortification of sachet water or other vehicles, (ii) expand entomophagy, (iii) strengthen nutrition education through the schools and health services, (iv) integrate calcium supplements or top calcium-providing food options into social protection programs such as school feeding initiatives.

This thesis not only contributed to the understanding of calcium intake in rural Ghana but also offered practical insights and recommendations that can inform future research, public health

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policies, and educational programs aimed at mitigating calcium deficiencies. It hopes to attract attention to these issues and support future studies and policies. By addressing these gaps, policymakers and health professionals can develop more effective strategies to improve calcium intake in rural Ghana, ultimately enhancing health outcomes for women.

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Appendices

Appendix 1. Typical food combination in sample meals of Ghanaian women in the current study

Folson et al. have complied an atlas of commonly consumed foods in Accra, representing the most comprehensive resource currently available on Ghanaian food combinations in meals (Folson et al., 2022). The table and figure collectively depict the typical meal composition found in Ghanaian cuisine. Ghanaian culinary traditions contain a diverse range of stews and soups, with key ingredients of tomato, onions, pepper, ginger, and an array of spices. Stews, known for their thickness, are often served alongside boiled or fried tubers, such as yam or plantains (figure). On the other hand, soups, known for their watery texture, are typically paired with cereal or tuber-based stiff porridges made from cassava, plantain, and maize, rice. One-pot dishes are often eaten alone. However, the food combinations of meals vary across households in Ghana, and are usually based on what ingredients individuals have available at home (Amoako, 2021). Second table shows common examples of meals consumed in Ghana which are inspired from Folson et al. food atlas.

Table. Classifications to describe the Ghanaian cuisi

Cereal or Tuber-based stiff porridges	Fermented: banku, kenkey Ga or Fante
	Not fermented: Akple, <i>fufu</i> , kokonte, rice balls
Tubers, side dishes	Boiled or fried ripe and unripe plantain, boiled or fried
	yam
Proteins	Chicken, eggs, fish, beef, grasscutter
Popular stews	Agushie stew, kontomire stew, beans stew, okra stew
Popular soups	Okra soup, palm nut soup, groundnut soup
Snacks	Gari soaking, mashed Kenkey
One-pot dish	Instant noodles, jollof rice, waakye

Folson et al. (2020)



Figure. Two typical lunch / dinner dish composition in Ghana

Food items	Estimated average intake	Frequency in dataset	Calcium provided per average intake	Calcium provided in meal
Gari soaking	103.12	54	44.35	57.26
groundnuts	29.57	29	13.01	57.50
Boiled plantain	425.86	48	34.07	
smoked tuna fish	32.28	816	6.13	56.55
garden egg stew	146.01	87	16.35	
Boiled plantain	425.86	48	34.07	140.2
beans stew	240.06	6	115.23	149.5
Boiled plantain	425.86	48	34.07	222 6
kontomire stew	281.39	193	188.53	222.0
Fried yam	134.8	26	13.48	
grounded pepper	77.04	524	7.17	159.87
fried fish	38.67	323	139.22	
Banku	445.64	809	111.41	
grounded pepper	77.04	524	7.17	552 61
shitor	20.24	7	295.84	333.04
fried fish	38.67	323	139.22	
Banku	445.64	809	111.41	
okra soup	170.76	87	87.09	198.5
wele	29.13	57	0	
Banku	445.64	809	111.41	
palm nut soup	237.41	480	90.22	207.76
tuna	32.28	816	6.13	
Kenkey	338.8	152	84.7	
grounded pepper	77.04	524	7.17	526.02
shitor	20.24	7	295.84	520.95
fried fish	38.67	323	139.22	
bean stew	240.06	6	115.23	
Kenkey	338.8	152	84.7	339.15
fried fish	38.67	323	139.22	
grounded pepper	77.04	524	7.17	
Kenkey	338.8		84.7	164.14
sardine	18.96	15	72.27	
Fufu	341.41	583	34.14	102 21
light soup	234.71	307	68.07	102.21

Table. Examples of common food combinations in Ghanaian cuisine

Fufu	341.41	583	34.14		
groundnut soup and okra	234.2	24	94.85	128.99	
Fufu	341.41	583	34.14	124.26	
palm nut soup	237.41	480	90.22	124.30	

The average intakes are derived from the first phase of this study

Appendix 2. Focus group discussion interview guide Questions	Aim
Let's start with what people like to eat. I would like to know what your favorite foods are.	Icebreaker question
Imagine one of your friends have a broken leg, what do you suggest him/her to eat? Probe: What is special about that food?	Warm up question
I have some pictures of different foods. Look them over and I would like to ask you to group them based on those that are good for your bones. ¹	Food cards activity
I see you have separated some of the foods as being good for bones, how do you know this? where have you gotten this information from?	Source of knowledge
I am choosing some of the foods, including the smoked small fish, fried fish, canned sardines, fish powder, local milk powder, <i>kontomire</i> , okra, <i>banku</i> , and <i>kenkey</i> . Which of these foods do you not eat regularly? Tell me more about the	Barriers to consuming calcium providers
reason? Now, if you want to take someone to a place to buy foods that are good for bones, where would you take them?	Market assessment question
Is there any other food that is good for bone but not included in cards? What surprised you from today's discussion?	Closing questions

Appendix	2.	Focus	group	disci	ussion	inte	erview	guide
repending	·	I OCUS	Stoup	uisci	1001011	1110		Suinc

¹ "good for bone" is considered to be equal to "calcium-rich" foods as during the pilot group women had difficulty understanding the calcium by its name.

	Food item name	Ingredients or description				
1. Turkey berries		Scientific name: Solanum torvum				
		A common vegetable in Ghana which contain 18.3 mg iron, 2.9 mg				
		zinc, and 61.1mg magnesium per 100g. It is eaten either raw or				
		cooked, mostly used in various stews or as a drink in rural Ghana.				
2.	Kontomire	Scientific name: Colocasia esculenta				
		Cocoyam leaves, a vegetable consumed mostly in kontomire stew. It				
		contains 107 mg calcium, 2.25 mg iron, 45mg magnesium, and				
		52mg vitamin C per 100g.				
3.	Groundnuts	Peanuts, which are mostly eaten roasted as a snack, processed to				
		form paste for preparing soup, or added to various porridges.				
4.	Plantain	Plantain is a plant classified as tubers in Ghanaian FBDG which				
		looks like banana. It is mostly eaten cooked and fried in main dishes				
		or deep fried as chips as a snack				
5.	Garden egg	A popular eggplant-shaped vegetable mostly used in stews.				
6.	Maize	Corn				
7.	Fish powder	Any type of dried fish which is grounded into a powder. It is mostly				
		used as a condiment in various stews and soups.				
8.	Grasscutter	Greater cane rat (Thryonomys swinderianus)				
		A popular animal-source food in Ghana which is consumed mostly				
		smoked and added into soup.				
9.	Palm oil	There are two types of palm oil: palm kernel oil and red palm oil				
		and they are produced and consumed fresh in rural areas				
10.	Kenkey	A stiff porridge made of corn dough which has two types:				
		Ga kenkey is wrapped with corn leaves				
		Fante kenkey is wrapped with plantain leaves				
11.	Banku	A stiff porridge made of corn and cassava dough				
12.	Fufu	A stiff porridge made of pounded boiled cassava and plantain				
13.	Kokonte	A stiff porridge made of cassava flour				
14.	Kaafa	Grounded corn kernel cooked with added sugar				

Appendix 3. Definition of food items named in this study

		It is mostly consumed as a snack along with groundnuts.
15.	Gari soaking	It is a mixture made with gari, water, sugar, and milk powder (if
		available), served with roasted groundnuts. Gari is roasted cassava
		flour.
16.	Bread	There are three types of bread in Ghana: sugar bread, tea bread,
		butter bread, and packaged toast bread.
17.	Wele	Cow's skin without any other parts is boiled and eaten in various
		stews.
18.	Sobolo	A cold red coloured drink made of boiled Hibiscus flower,
		pineapple, cloves, grains of selim, ginger, pepper, and other
		condiments for flavour.
19.	Light soup	A soup made of tomatoes, onions, garlic, ginger
20.	Palm nut soup	A soup made of palm nut paste or cream, onion, pepper, garlic,
		other vegetables of choice (mostly garden eggs or okra), any type of
		smoked fish at hand
21.	Kontomire stew	A stew made of cocoyam leaves, onion, oil, with added smoked
		meat or fish of choice, often served with yam and/or plantain

Kontomire https://fdc.nal.usda.gov/fdc-app.html#/food-details/168487/nutrients

Food items	Excerpts				
Kokonte	"What I would recommend to him is kokonte with palm soup because kokonte helps you recover from wounds faster. Because women who give birth newly are sometimes given kokonte to help them recover from the wound of birth (FGD 1, Pos. 47)"				
	"Kokonte is a portion of food that heals wounds that's why it's necessary to give someone with a broken bone kokonte. (FGD 2, Pos. 73)"				
	"Kokonte is starchy, and they don't allow them to eat (FGD4, Pos. 54)"				
Malt	"Will give the person malt and milk because it gives him blood (FGD 1, Pos. 57)"				
Kaafa	"The Kaafa will make her lightweight and help her recover faster. (FGD 2, Pos. 61)"				
	"It helps recover broken bones faster (FGD 2, Pos. 259)"				
	"Kaafa is not heavy when one eats, turkey berries provide blood, and powdered fish also gives blood, so all these three will help him recover faster. (FGD 6, Pos. 100)"				
<i>Fufu</i> made with more	"Inside the fufu, the plantain should be put more than cassava so that the starch won't be too much (FGD 3, Pos. 47)"				
plantain	"mix the fufu with a lot of plantain or cocoyam You yourself will see that the person is healing (FGD5, Pos. 99)"				
Yam	"She can also eat yam because it won't make the person heavy so walking will be easy for the person and that will help her heal faster. (FGD 2, Pos. 67)"				
	"The food should be attractive. For example, now we are in yam season so we should prepare and cook it. You cook stew like with tuna and yellow yam (FGD 7, Pos. 71)"				

Appendix 4. Food items reported by women in addition to the food cards presented to them in focus group discussions

phase of the	e study
Source	Some example excerpts
Healthcare	"Sometimes when we visit the pharmacy, they educate us on food good for bone or
staff	treatment of sickness (FG2- Pos.200)."
	"I learned it from the doctor. They told me to eat dry fish or salmon. (FG4- Pos.364)"
School	"I learnt from the school (FG3- Pos.217)."
	"Sometimes our children also tell us after school (FG2- Pos.200)."
Unknown	"When I gave birth to my child he couldn't walk for some time, so someone advised
people	me to give him beef and especially its bones. Then you need to give the broth to the
	baby. I also learned it from a circle of people in my house. (FG1- Pos.345)"
	"Through conversations with others. (FG3- Pos.214)"
	" The madam that I work with said if you cook the okra and you don't cut the heat
	and you cook everything at the same time, it is good for the bone and the body (FG4-
	Pos.124)"
	"If we travel, we sometimes learn at the wedding. If we go to those places sometimes,
	they discuss, and we hear what is good. (FG5- Pos.276)"
Personal	"Personal experience because when I eat these foods, I have joint pains so after I ate
experience	these foods the condition becomes better the following day (FG1- Pos.348)."
	"Sometimes you prepare some food like <i>banku</i> and stew and <i>fufu</i> and soup or tea and
	breadand when you are very observant you yourself will realize they help you in a
	way. You feel it (FG5- Pos.278)."
Parents	"I learnt from home; my parents taught me that (FG5- Pos.263)."
	"My Mom (FG1- Pos.341).
Herbalist	"Herbalist who treats broken bones. (FG2- Pos.198)"
	"If your family is sick, you send him to the herbalist and you learn from there. (FG2-
	Pos.204)"
Books	"I learnt from books. (FG3- Pos.220 / FG6- Pos.298)"
City	"I stay in the city before, so I learned from there. All these are not new things to me. If
	you give it to me, I will eat. (FG4- Pos.357)"
TV	"In the house and the TV. (FG3- Pos.221)"

Appendix 5. Source of nutritional information of the rural Ghanaian women in the second phase of the study

This FGD "I learnt from this discussion (FG3- Pos.212)."

Food items	Cedis /100 g ^a	USD /100 g ^a	mg Ca/ 100 g ^b	USD / mg Ca
Smoked Amani ^g	12.9	0.89	1481	0.0006
Fried mackerel	8.4	0.58	360	0.0016
Cooked anchovies	11.7	0.81	232	0.0035
Canned sardines	7.9	0.54	381	0.0014
Fish powder	29.4	2.03	3580	0.0006
Banku ^h	0.9	0.06	25	0.0024
Fufu ^h	1.2	0.08	10	0.0080
Kenkey Ga ^h	0.8	0.06	22	0.0027
Local milk				
powder	20.6	1.42	900	0.0016
[brand1]				
Local milk				
powder	11.5	0.79	830	0.0010
[brand 2]				
Orange	1.7	0.11	40	0.0028
Mango	1.5	0.10	11	0.0091
Beef	4.5	0.31	12	0.0258
Chicken	5.3	0.37	15	0.0247
Raw egg	3.4	0.24	50	0.0048
Fresh okra	1.1	0.08	65	0.0012
Kontomire	0.6	0.04	59	0.0007
Roasted groundnuts	5.1	0.35	44	0.0080

Appendix 6. The average cost of food items collected from two rural markets in Eastern Region of Ghana

Ca: calcium; USD: US dollars; Cedis: Ghanaian Cedis

Dairy products including milk and yoghurt could not be found on neither of markets.

^a The average price of food items from two assessed food was initially recorded in Ghanaian Cedis, then converted to USD using May 2024 exchange rates.

^b Calcium content of food is acquired from the local food composition database.

^c The average consumption (g per day) of the population is calculated from phase 1 of the study. The average consumption of fish powder and *kontomire* (cocoyam leaves) was not retractable from the dataset because they were added to stews and soups.

^d Price of food item for a 129-mg increase in calcium

^e Grams of food item needed for 129 mg of calcium intake

^f Energy intake provided if a 129-mg increase calcium intake happens.

^g Amani is the local name for herring

^h Check Appendix 3 for Ghanaian food item's definitions.

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