



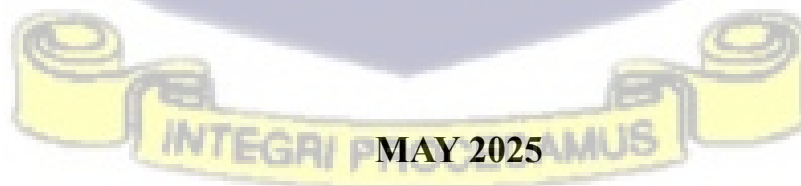
UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

**PERCEPTION AND ACCEPTANCE OF MICRONUTRIENT-
FORTIFIED BOUILLON CUBES AMONG NON-INDEX
HOUSEHOLD MEMBERS IN A RANDOMISED TRIAL IN TWO
DISTRICTS OF NORTHERN GHANA**

FELIX KWAKU KYEREH

DEPARTMENT OF NUTRITION AND FOOD SCIENCE



MAY 2025

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BY

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA,
LEGON, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF DOCTOR OF PHILOSOPHY IN NUTRITION**

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

INTEGRI PROCEDAMUS

MAY 2025

DECLARATION

I, Felix Kwaku Kyereh, hereby affirm that this thesis is my original work, completed under the guidance and supervision of Prof. Seth Adu-Afarwuah and Dr. Agartha Narki Ohemeng at the Department of Nutrition and Food Science, University of Ghana, and Prof. Reina Engle-Stone at the Institute for Global Nutrition, University of California, Davis. All references cited in this thesis have been duly acknowledged.



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DEDICATION

I dedicate this work to my family, especially my mother whose unwavering support and encouragement have been my greatest source of strength throughout this journey. And to all those who have believed in me and inspired me to pursue my goals.



ABSTRACT

Background: Micronutrient deficiencies remain a major global health challenge, disproportionately affecting women of reproductive age and pre-school children in low- and middle-income countries (LMICs). In northern Ghana, inadequate nutrient intake may contribute to high rates of iron and iodine deficiencies exceeding 40% among pre-school children. These deficiencies contribute to adverse health outcomes and exacerbate socio-economic disparities. Bouillon cubes, a condiment consumed by over 90% of households in northern Ghana, offer a culturally acceptable and scalable vehicle for delivering essential micronutrients through fortification. Researchers in the Condiment Micronutrient Innovation Trial (CoMIT) project conducted a randomised controlled trial (RCT) to evaluate the impact of household use of multiple micronutrient-fortified bouillon cubes among non-pregnant, non-lactating women of reproductive age (WRA), lactating women 4–18 months postpartum (LW), and pre-school children aged 2–5 years (PSC) in the Kumbungu and Tolon districts of northern Ghana. However, the perceptions and acceptance of these bouillon cubes among household members not enrolled in the RCT (non-index household members) remain unexplored.

Objectives: The main objective of this study was to investigate the perceptions and acceptance of micronutrient-fortified bouillon cubes among non-index household members (NIHM) of WRA, LW and PSC participating in the CoMIT project RCT. Specific objectives were to (1) develop and validate a questionnaire to measure perception and acceptance of micronutrient-fortified bouillon cubes ; (2) analyse the changes in perception and acceptance during the intervention, identifying key drivers and barriers; and (3) evaluate the associations between the perceptions and acceptance of NIHMs and the haemoglobin (Hb) and spot urinary iodine

concentration (UIC) of index participants (WRA and PSC) in the CoMIT RCT and examine household-level factors as effect modifiers.

Methods: This study was a longitudinal mixed-methods study that involved NIHMs (≥ 15 years) from households of index participants enrolled in the CoMIT RCT in the Kumbungu and Tolon districts of northern Ghana. The index participants were WRA ($n = 1,028$), LW ($n = 690$), and PSC ($n = 690$), recruited through door-to-door visits using the random walk method. After consent was obtained for the index participant, one NIHM was randomly selected from the household roster using the Kish Table. Following baseline assessments of index participants, households were randomised to receive biweekly rations of either (a) multiple micronutrient-fortified bouillon cubes (containing folic acid, vitamin A, vitamin B12, iodine, iron, and zinc) or (b) control cubes containing iodine only, to be used in household cooking over a 9-month period. Quantitative data were collected from NIHMs at three time points: pre-intervention (T0; $n = 1,047$), early intervention (T1, within the first two months of the intervention; $n = 731$), and late intervention (T2, within the final two months of the intervention; $n = 796$). At T0, background characteristics were assessed using structured instruments. At T1 and T2 NIHMs' perception and acceptance of the *study bouillon cubes* were assessed using a 29-item questionnaire, with most items eliciting responses on a 5-point Likert scale. Focus group discussions (FGDs; $n = 24$) were conducted at mid-intervention to explore health, sociocultural, sensory, and economic factors influencing NIHMs' perception and acceptance of the study bouillon. Among enrolled WRA and PSC, Hb (g/dL) and spot UIC ($\mu\text{g/L}$) were measured at baseline and endline. Eighteen items specific to the study bouillon cubes (8 for perception, 10 for acceptance) were identified and validated using exploratory (EFA) and confirmatory (CFA) factor analyses of T1 data. Composite scores were computed as normalised, weighted means of validated items at T1 and

T2, with higher scores indicating greater perception or acceptance. Statistical analyses included (a) Bayesian linear mixed-effects models to evaluate longitudinal changes in perception and acceptance and identify key drivers, and (b) Generalized Estimating Equations (GEEs) alongside Generalized Additive Mixed Models (GAMMs) to examine associations between NIHMs' perceptions or acceptance and index participants' Hb and spot UIC and household-level factors modifying these associations. Analyses were adjusted for pre-defined covariates (e.g. sex, age, food insecurity, and socio-economic status) that were significant at $p \leq 0.1$, as well as baseline Hb and UIC for models examining the association between NIHMs' perceptions or acceptance and index participants' Hb and spot UIC. Baseline household-level factors (e.g. household head's age, socio-economic status, bouillon consumption, household size) were tested as effect modifiers. Focus group discussions (FGDs) data were analysed using Braun and Clarke's six-phase framework, complemented by Latent Dirichlet Allocation to identify thematic patterns in participants' responses.

Results: A total of 1,047 NIHMs (mean age 40.0 ± 14.7 years; 59% female; 74.5% without formal education) provided responses. Exploratory factor analysis identified two constructs, Perception (8 items) and Acceptance (11 items), explaining 56% of variance. Confirmatory factor analysis retained 18 items (Perception=8; Acceptance=10) and showed good model fit (chi-square/df=1.91, root mean square error of approximation [RMSEA]=0.04, comparative fit index [CFI]=0.98, Tucker–Lewis index [TLI]=0.98, and standardised root mean square residual [SRMR]=0.06). Internal consistency was (Cronbach's alpha = 0.71 for Perception and 0.72 for Acceptance). Between T1 and T2, the mean $\pm$ SD perception score for the study bouillon cubes increased significantly from 3.4 ± 1.1 to 4.1 ± 0.6 (adjusted mean difference = 0.74, 95% CrI: [0.63, 0.86]). In contrast, the acceptance score remained consistently high (4.59 ± 0.38 to $4.58 \pm$

0.35; adjusted mean difference = -0.01 , 95% CrI: $[-0.06, 0.04]$). These patterns were similar across intervention arms. At both time points, more positive perception scores were observed among wives, children, and parents compared to household heads, and among urban compared to rural residents. Perception scores were lower among formal employees than among farmers. Interaction effects showed greater increases in perception scores from T1 to T2 among formal employees and small business owners compared to farmers, and smaller increases among wives, children, and parents compared to household heads. Higher acceptance was associated with being male, owning a small business, and having higher household socio-economic status (SES). Acceptance was lower among urban residents, those with higher baseline bouillon consumption, and mildly food-insecure households, but higher among severely food-insecure households. The FGDs further revealed that perceived health benefits, favourable sensory attributes, and cultural compatibility contributed to the sustained high acceptance of the study bouillon cubes, whereas barriers to perception and acceptance included misconceptions (e.g., fears of long-term male infertility) and occasional changes in food colour. In adjusted GEE models, NIHMs' perception and acceptance scores at T1 and T2 showed no significant association with endline Hb concentration in PSC or WRA. However, significant effect modification by household factors was observed. In PSC models, perception and acceptance at T2 interacted significantly with the household head's age and baseline bouillon consumption. The negative interaction with age indicates a weaker association at higher household head ages, while the positive interaction with baseline bouillon consumption suggests a stronger association at higher consumption levels. In WRA models, acceptance at T1 and T2 interacted significantly with household head age (negative and positive directions, respectively), and with SES and household size at T2 (positive and negative directions, respectively). Perception at T2 also interacted with household bouillon

consumption and SES (positive direction). Adjusted GAMMs revealed complex associations between NIHMs' perception and acceptance scores and endline UIC. In PSC, perception at T1 showed a non-linear association with UIC, while acceptance at T1 and T2 showed positive linear associations. In WRA models, both perception and acceptance scores at T1 and T2 were significantly associated with UIC in non-linear patterns. These associations were strongest in male-headed households, those with basic education, and households experiencing food insecurity.

Conclusion: This study developed and validated a tool to assess household perceptions and acceptance of fortified bouillon cubes. The findings show that perceptions improved over time and acceptance remained consistently high, suggesting that fortified bouillon cubes are a culturally appropriate and widely accepted fortification vehicle in northern Ghana. While NIHMs' perception and acceptance were not directly associated with endline haemoglobin levels in PSC and WRA, these relationships were modified by household-level factors. In contrast, both perception and acceptance were significantly associated with endline urinary iodine concentration, with patterns varying according to household characteristics, including the sex of the household head, education level, and food security status. These findings support the need for complementary implementation strategies to enhance the nutritional impact of bouillon cube fortification programmes, particularly among vulnerable households.



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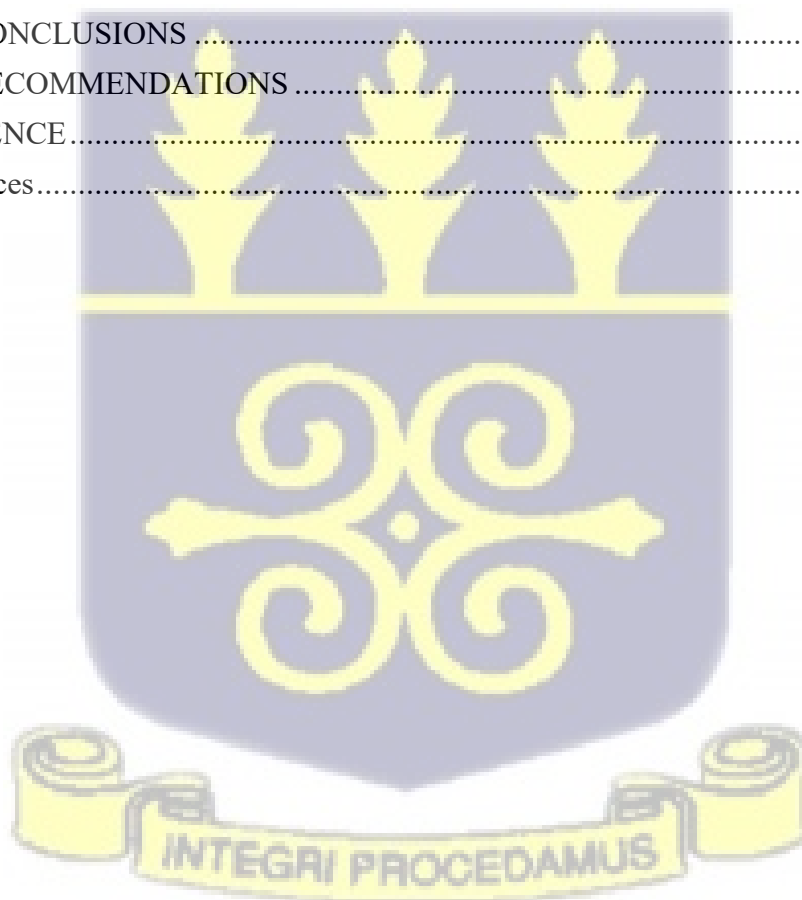
Finally, I express my sincere gratitude to the Ghana National Petroleum Corporation for funding my tuition for three years. Your generous support made my academic journey possible.

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ABBREVIATIONS AND ACRONYMS

CFA	Confirmatory Factor Analysis
CoMIT	Condiment Micronutrient Innovation Trial
EFA	Exploratory Factor Analysis
FGDs	Focus Group Discussions
GAMM	Generalized Additive Mixed Model
GEE	Generalized Estimating Equations
HFIAS	Household Food Insecurity Access Scale
HBM	Health Belief Model
LMICs	low- and middle-income countries
LW	non-pregnant, lactating women
LSFF	Large-scale Food Fortification
MNDs	Micronutrient deficiencies
PSC	pre-school children aged 2–5 years
RCT	Randomised Controlled Trial
SDGs	Sustainable Development Goals
SES	Socio-economic Status
TPB	Theory of Planned Behaviour
UIC	Urinary Iodine Concentrations
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VAD	Vitamin A Deficiency
WHO	World Health Organization
WRA	non-pregnant, non-lactating women aged 15–49 years



OPERATIONAL DEFINITIONS

Acceptance: Acceptance refers to the willingness of household members to use and regularly consume the study-supplied bouillon cubes. In this study, acceptance was assessed using a positive preference score.

Fortified Bouillon Cubes: Fortified Bouillon Cubes are concentrated seasoning cubes used in cooking, and in this study, they are fortified with essential micronutrients.

Household Dynamics: The interactions and relationships among household members that influence decision-making and behaviour.

Non-Index Household members: Individuals aged 15 years and older residing in households of index participants (women and children) enrolled in the Condiment Micronutrient Innovation Trial (CoMIT) randomised controlled trial. These individuals consumed the same meals prepared with the trial-supplied bouillon cubes.

Micronutrient Deficiencies (MNDs): Micronutrient Deficiencies (MNDs) result from a lack of essential vitamins and minerals in the diet, which can affect overall health and development.

Perception (Opinion and Attitude): Perception refers to household members' beliefs, thoughts, and feelings about the fortified bouillon cubes. It includes participant opinions (what they think about the bouillon cubes) and attitudes (how they feel about using and consuming them). In this study, perception was assessed using a positive preference score.

Randomised Controlled Trial (RCT): A study design randomly assigns participants to an intervention or control group to measure the intervention's effectiveness.

PART ONE: INTRODUCTION AND LITERATURE REVIEW



CHAPTER ONE

INTRODUCTION

1.0 Background

Micronutrient deficiencies (MNDs), commonly referred to as “hidden hunger”, present a significant global public health issue, particularly in low- and middle-income countries (LMICs). These deficiencies, often resulting from inadequate intake of essential vitamins and minerals, can lead to adverse outcomes such as anaemia, cognitive impairments, and increased susceptibility to infections (Bailey et al., 2015; Stevens, Paciorek, et al., 2022; WHO, 2024a).

A pooled analysis of micronutrient status data from 24 countries found that 56% of pre-school children (PSC) and 67% of women of reproductive age (WRA) lacked at least one essential micronutrient (folate, iron, and zinc in WRA; and iron, vitamin A, and zinc in children) (Stevens, Beal, et al., 2022; WHO, 2024a). These statistics underscore the urgent need for targeted nutritional interventions in vulnerable populations.

In Ghana, MNDs are particularly severe in the northern regions, where vitamin A and iron deficiencies and anaemia affect significant portions of pre-school children and non-pregnant women aged 15–49 years. The Ghana Micronutrient Survey reported that 40% of pre-school children in the northern belt are iron deficient, compared to 18% in the middle and 13% in the southern belts. Similar disparities exist for vitamin A deficiency and anaemia rates, with northern Ghana consistently experiencing higher prevalence (University of Ghana et al., 2017). These deficiencies are exacerbated by limited access to nutrient-dense foods, economic challenges, and reliance on inexpensive, nutrient-poor staples (Abizari, Azupogo, et al., 2017; Petry et al., 2021).

Micronutrient deficiencies (MNDs) impose a significant economic burden globally, with undernutrition and MNDs collectively resulting in productivity losses exceeding US\$1 trillion annually (World Bank, 2022). Iron deficiency anaemia contributes substantially to these losses. In Ghana, the economic burden of iron deficiency-related anaemia is estimated at approximately US\$100 million annually in healthcare costs and lost productivity (USAID Advancing Nutrition, 2023).

1.1 The Potential of Food Fortification

The World Health Organization (WHO) identifies large-scale food fortification (LSFF) as a cost-effective strategy to combat micronutrient deficiencies (MNDs) (Rowe, 2020; WHO, 2024b). LSFF has demonstrated efficacy in reducing anaemia and goitre prevalence by 34% and 74%, respectively (Keats et al., 2019). However, a recent global modelling analysis of nutrient intake from food, excluding the contributions of fortification and supplementation, revealed alarming inadequacies in nutrient intake: 68% of the global population consumes insufficient iodine, 65% insufficient iron, and 54% insufficient folate (Passarelli et al., 2024).

Despite these global achievements in LSFF, Ghana's LSFF coverage remains low, with only 36% of cooking oils and 6% of wheat flour meeting fortification standards in the northern belt regions (UNICEF, 2017). Beyond accessibility, cultural perceptions and mistrust often hinder the acceptance of fortified foods, highlighting the need for innovative, culturally sensitive interventions (Geicu-Cristea et al., 2024; Gosdin et al., 2021).

Bouillon cubes, a ubiquitous condiment in Ghanaian households, offer a promising vehicle for micronutrient delivery. Widely used, especially in low-income and rural

communities (Hess et al., 2013; Matthias et al., 2022; Moretti et al., 2018), fortified bouillon cubes can significantly contribute to nutrient intake. Evidence indicates that 72% of households in Northern Ghana regularly use bouillon cubes in meals, making them an ideal means for micronutrient delivery (Kumordzie et al., 2021). Additionally, fortified bouillon cubes provide up to two-thirds of the iodine intake among school children in Northern Ghana (Abizari, Dold, et al., 2017). Importantly, the centralised production of bouillon cubes facilitates regulatory monitoring and compliance with fortification standards.

Building on these insights, the investigators of the Condiment Micronutrient Innovative Trial (CoMIT) Project conducted a randomised controlled trial (herein referred to as the CoMIT Trial) in the Tolon and Kumbungu districts of the Northern Region of Ghana evaluating the impact of multiple micronutrient-fortified bouillon cubes (containing iodine, vitamin A, folic acid, vitamin B12, iron, and zinc) compared to control bouillon cubes (fortified with iodine only). The study directly enrolled three target groups: (i) non-pregnant, lactating women (LW) aged 15–49 years at 4–18 months postpartum; (ii) non-pregnant, non-lactating women aged 15–49 years (WRA); and (iii) pre-school children aged 2–5 years (PSC). Households subsequently received the intervention bouillon cubes for use in household cooking over a period of nine months for WRA and PSC, and three months for LW. The main outcomes were changes in biomarkers of micronutrient status and blood haemoglobin concentration among the enrolled WRA and PSC, and milk micronutrient concentrations among the enrolled LW (Engle-Stone, Wessells, et al., 2024).

1.2 Rationale of the Present Study

Micronutrient fortification interventions fundamentally depend on household perceptions, acceptance, and consistent use of fortified products (de Barros & Cardoso, 2016; GAIN, 2023a). In the context of the CoMIT randomised controlled trial (RCT), the potential impact of micronutrient-fortified bouillon cubes ((herein referred to as study-supplied bouillon cubes) on study endpoints among enrolled LW, WRA, and PSC may be influenced by the perceptions and acceptance of other household members not enrolled in the trial, such as household heads and cooks. These household members often determine whether, and to what extent, the study-supplied bouillon cubes are used in meal preparation (Christian et al., 2016; Katenga-Kaunda et al., 2022).

Previous studies have documented several health benefits of micronutrient fortification interventions, including significant improvements in haemoglobin concentrations, reductions in iron-deficiency anaemia, and enhanced overall micronutrient status among women and children (Azupogo et al., 2024; Das et al., 2019; Ekoe et al., 2020; Keats et al., 2019; Larson et al., 2021). Additionally, studies have reported positive perceptions and acceptance among participants and caregivers involved in child nutrition interventions, such as micronutrient supplementation and fortified complementary food programmes (Adu-Afarwuah et al., 2008; Creed-Kanashiro et al., 2016; de Barros & Cardoso, 2016; Kyei-Arthur et al., 2020). However, these studies often overlook broader community-level dynamics. This gap is especially relevant in interventions where randomisation occurs at the household rather than the individual level, as in the CoMIT trial (Lamstein et al., 2014). In such contexts, all household members are affected by the intervention, yet their perceptions and acceptance remain underexplored. This limits our

understanding of the full effectiveness of fortification interventions at household and community levels.

Therefore, this study explores the perceptions and acceptance of study-supplied bouillon cubes among non-enrolled household members (hereafter referred to as non-index household members [NIHMs]) within the CoMIT project in northern Ghana. It also examines the associations between household-level behaviours (perceptions and acceptance of NIHMs) and clinical outcomes of CoMIT trial participants (herein index participants), specifically haemoglobin (Hb) concentrations and spot urinary iodine concentration (UIC).

1.3 Significance and Contribution to Knowledge

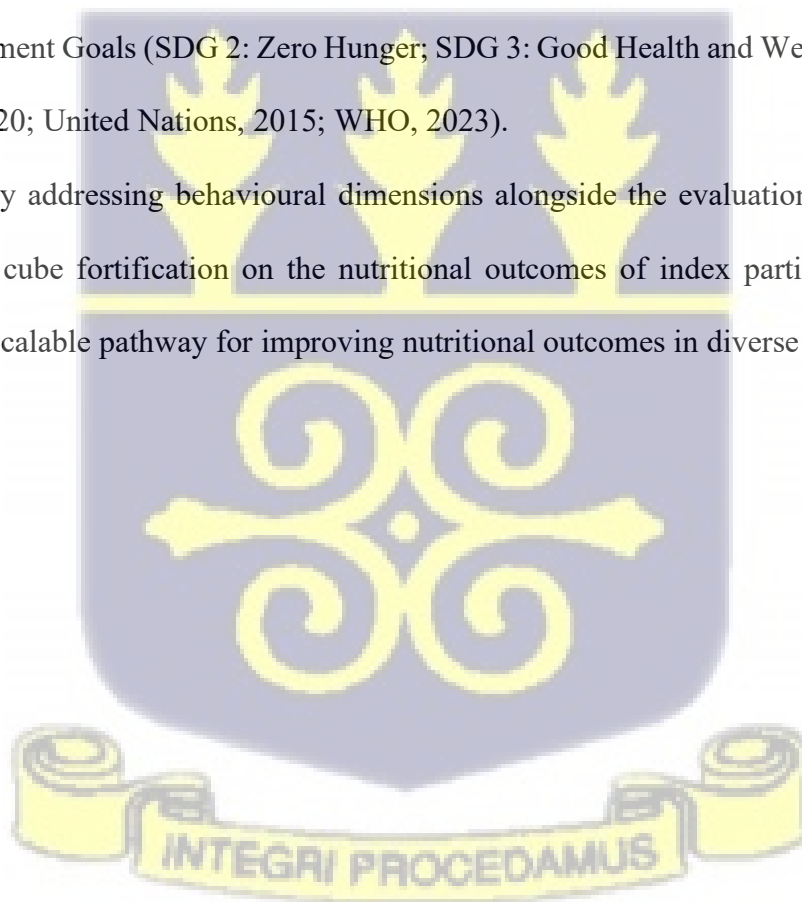
This study provides empirical evidence on the perceptions and acceptability of micronutrient-fortified bouillon cubes at the household level, emphasising the essential role of household dynamics in shaping the success of fortification programmes (Gebre et al., 2023; Mkambula et al., 2020). It addresses a key gap in the literature by linking household perceptions and acceptance with clinical outcomes, such as Hb levels and UIC, within an RCT framework (Das et al., 2019).

Practically, the findings identify key drivers and barriers to perceptions and acceptance, offering actionable insights for designing culturally and contextually relevant fortification programmes. These insights can support the sustainability and widespread use of micronutrient-fortified bouillon cubes in Ghana and other low- and middle-income countries (GAIN, 2023a; Harris-Fry et al., 2017).

A major methodological contribution of this study is the development and validation of a novel, culturally adapted tool for assessing household perceptions and acceptance of fortified bouillon cubes. The tool is grounded in established behavioural theories, specifically the Theory of Planned Behaviour (TPB) and the Health Belief Model (HBM), thereby strengthening its theoretical relevance and applicability in diverse settings. This instrument fills an important gap in existing research, where validated tools for measuring perception and acceptance of fortified condiments are limited.

Globally, this research contributes to the development of public health frameworks that integrate household dynamics and inform policies aligned with the Sustainable Development Goals (SDG 2: Zero Hunger; SDG 3: Good Health and Well-being) (Hawkes et al., 2020; United Nations, 2015; WHO, 2023).

By addressing behavioural dimensions alongside the evaluation of the impact of bouillon cube fortification on the nutritional outcomes of index participants, the study offers a scalable pathway for improving nutritional outcomes in diverse cultural contexts.



CHAPTER 2

LITERATURE REVIEW

2.1 Micronutrient Deficiencies (MNDs)

Micronutrient deficiencies continue to present major health and economic challenges in low- and middle-income countries (LMICs), particularly affecting vulnerable groups such as children and women of reproductive age. Despite numerous interventions, micronutrient deficiencies (MNDs) persist, affecting millions and leading to severe health consequences such as impaired cognitive development, weakened immunity, increased maternal and child morbidity, and higher risks of mortality, as well as substantial economic burdens (Stevens, Beal, et al., 2022; WHO, 2024a)

Deficiencies in iron, vitamin A, zinc, and folate disproportionately affect vulnerable populations such as children under-five and women of reproductive age (WRA) (Stevens, Beal, et al., 2022; Stevens, Paciorek, et al., 2022). A pooled analysis across 24 countries revealed that nearly 50% of pre-school age children and 67% of WRA are deficient in at least one essential micronutrient, resulting in adverse health outcomes and reduced economic productivity (Stevens, Beal, et al., 2022).

Sub-Saharan Africa and South Asia bear the heaviest burden, with 62% of pre-school children and 80% of non-pregnant WRA affected in sub-Saharan Africa (WHO, 2024a). These deficiencies contribute to disease susceptibility, impaired physical and cognitive development, and pregnancy complications. In Ghana, the northern regions experience particularly high rates of MNDs due to limited dietary diversity and economic constraints that restrict access to nutrient-rich foods (Petry et al., 2021; Wegmüller et al., 2020).

2.2 Implications of Micronutrient Deficiencies

Micronutrient deficiencies (MNDs) severely impair health and impose significant economic costs, particularly in low- and middle-income countries. Deficiencies in iron, vitamin A, iodine, zinc, folate, and vitamin B12 are associated with impaired cognitive and physical development, increased susceptibility to infections, and complications during pregnancy, which collectively hinder socio-economic progress by reducing educational attainment and productivity (Bailey et al., 2015; WHO, 2024a).

In Ghana, MNDs are notably prevalent in the northern regions, where vulnerable groups, including children under-five and women of reproductive age (WRA), experience poor cognitive development, high morbidity, preterm delivery, and stunted growth (UNICEF, 2017; Wegmüller et al., 2020). The economic burden is profound. Iron deficiency anaemia alone costs Ghana an estimated US\$100 million annually, while the cumulative impact of stunting and cognitive impairments due to iodine deficiency has resulted in losses of approximately 7.9 billion cedis (around US\$5.5 billion) between 2011 and 2020 (GLOPAN, 2016; Hoddinott & Rosegrant, 2013; USAID Advancing Nutrition, 2023). These deficiencies also lead to lost productivity and increased healthcare costs, straining both households and the national economy.

2.3 Key Micronutrient Deficiencies

Iron deficiency affects over 1.62 billion people globally, leading to anaemia, cognitive impairments, and adverse pregnancy outcomes (Bailey et al., 2015; WHO, 2024a). In sub-Saharan Africa, anaemia affects 62% of pre-schoolers and 30% of WRA, with iron

deficiency being a leading cause in both groups. The prevalence of iron deficiency exceeds 40% in northern Ghana (Stevens, Paciorek, et al., 2022; UNICEF, 2017).

Vitamin A deficiency (VAD) affects over 330 million children globally and is a leading cause of preventable blindness (WHO, 2024c). In Ghana, VAD, assessed through retinol binding protein concentration ($<0.70 \mu\text{mol/L}$ and adjusted for inflammation), affects 20% of children and 13% of WRA, with prevalence rates of 31% in the northern belt, 18% in the middle belt, and 17% in the southern belt (University of Ghana et al., 2017).

Iodine deficiency impairs thyroid function and cognitive development (Zimmermann & Andersson, 2021). In northern Ghana, an intervention study that assessed iodine status among lactating women and their toddlers reported that at baseline, 29% of toddlers and 36% of the women exhibited iodine deficiency (Kubuga et al., 2019).

Zinc deficiency is prevalent in sub-Saharan Africa, contributing to growth retardation, impaired immune response, and increased susceptibility to infections (Dembedza et al., 2023; Stevens, Beal, et al., 2022). Stevens et al. (2022) estimated that zinc deficiency affects 20% or more of pre-school-aged children in several countries within the region (Stevens, Beal, et al., 2022).

In Ghana, stunting affects 17% of children under five, with rates exceeding 30% in the northern regions. While direct national estimates of zinc deficiency are limited, zinc's essential role in growth and immunity suggests it may contribute to these high stunting and infection rates (WHO, 2021). A study conducted in 2012 in the Manya-Krobo district reported a 40.5% prevalence of zinc deficiency among children, with higher risk observed in rural areas (Egbi, 2012).

Folate and vitamin B12 deficiencies are common in sub-Saharan Africa, leading to health issues such as megaloblastic anaemia and increased risk of neural tube defects (NTDs) in newborns (Rogers et al., 2018; Stevens, Beal, et al., 2022). According to Stevens et al. (2022), vitamin B12 deficiency affects 10–15% of the global population, with higher rates in South Asia and sub-Saharan Africa (Stevens, Beal, et al., 2022). In Ghana, folate deficiency affects about 58% of non-pregnant, non-lactating WRA, emphasising the importance of improving dietary intake and implementing supplementation programmes (UNICEF, 2017). Vitamin B12 deficiency is also a concern, with significant prevalence observed among WRA in Northern Ghana (UNICEF, 2017)

2.4 Interventions to Address Micronutrient Deficiencies

Among the various strategies used to combat micronutrient deficiencies, this review focuses on two widely used interventions: supplementation and food fortification. These strategies have been commonly applied in public health programmes, especially in low- and middle-income countries.

2.4.1 Supplementation Programmes

Targeted supplementation initiatives, such as iron and folic acid supplementation during pregnancy, have significantly reduced anaemia rates in many regions (Bhutta et al., 2013; Finkelstein et al., 2024). However, challenges such as adherence and accessibility limit their success in LMICs. Recent studies in Ghana highlight the effectiveness of targeted micronutrient interventions in addressing nutritional deficiencies (UNICEF, 2017; USAID Advancing Nutrition, 2023). For example, the Ten2Twenty-Ghana trial, a randomised

controlled study conducted in the Mion District, Northern Ghana, evaluated the impact of multiple micronutrient-fortified biscuits on adolescent girls (Azupogo et al., 2024). This 26-week trial involving 621 participants showed significant improvements in haemoglobin (mean difference = 3.8 g/L, $p < 0.05$) and plasma ferritin levels (mean difference = 9.4 $\mu\text{g/L}$, $p < 0.05$). These findings underscore the efficacy of fortified foods in addressing deficiencies among adolescents in resource-limited settings (Azupogo et al., 2024).

2.4.2 Food Fortification

Large-scale food fortification (LSFF) has proven effective in reducing deficiencies of essential micronutrients such as iron, iodine, vitamin A, and folic acid (Keats et al., 2019). For instance, fortifying staples like salt, flour, and oil has improved iron and vitamin A status among populations (GAIN, 2024; Garrett et al., 2019). In Ghana, mandatory fortification of table salt with iodine has helped reduce iodine deficiency (Abu et al., 2019). Additionally, home fortification with micronutrient powder has improved micronutrient status. For instance, a study involving 1,958 children aged 6 to 35 months in rural northern Ghana reported significantly higher haemoglobin and serum ferritin levels in the intervention group compared to the placebo group after five months of daily supplementation (Tchum et al., 2021). The prevalence of anaemia decreased more in the intervention group (55.52% vs. 62.63%, $p = 0.003$), and iron deficiency was significantly lower (19.71% vs. 28.56%, $p < 0.0001$) (Tchum et al., 2021). Further large-scale fortification efforts in Ghana have targeted iodized salt, wheat flour, and edible oils, with varying levels of success (Abu et al., 2019; Nyumuah et al., 2012).

Extensive research on micronutrient supplementation and fortification across various population groups, such as pregnant women, adolescents, and young children, has revealed measurable improvements in micronutrient status (Bhutta et al., 2013; Finkelstein et al., 2024; Tchum et al., 2021). However, sustained programme success depends not only on biological efficacy but also on household-level factors that influence product use and acceptability. Understanding the perceptions and acceptance of fortified foods among non-index household members is therefore critical to translating biological efficacy into real-world nutritional impact.

2.5 Behavioural and Cultural Barriers of Food Fortification

Behavioural and cultural factors play a decisive role in determining the acceptance and sustained use of fortified foods in sub-Saharan Africa. Although fortification has proven technically effective, social perceptions and cultural norms strongly influence whether fortified products are adopted at the household level (Huey et al., 2024). Misconceptions about taste, safety, and the perceived “unnaturalness” of fortified foods can discourage their use, particularly when fortification visibly alters the colour, flavour, or aroma (Bechoff et al., 2018; De Groote et al., 2020).

In Ghana and neighbouring countries, some consumers associate noticeable changes in fortified bouillon cubes or iodised salt with contamination or adulteration, reducing their willingness to use such products (Adams. et al., 2024; Wessells et al., 2024). Similar reservations have been reported in Uganda and Nigeria, where fortified or biofortified foods were viewed as “foreign” or “chemical” and therefore less wholesome than traditional or locally processed staples (Bechoff et al., 2018; Huey et al., 2024).

Traditional food beliefs also contribute to rejection; for instance, some communities perceive foods altered from their natural state as spiritually impure or less nutritious (Chakona & Shackleton, 2019). In Ghana, widespread preference for home-prepared condiments and grains milled by small local processors limits the substitution of these with commercially fortified alternatives (Nyumuah et al., 2012).

Dietary habits reinforce these barriers. Households that rely heavily on unfortified staples or locally produced condiments may perceive fortified foods as unnecessary or inconsistent with traditional cooking practices (De Groote et al., 2020). Moreover, gendered decision-making around household food preparation can shape adoption. Women, who are typically the main cooks, often prioritise sensory acceptability and family preferences over nutritional considerations (Huey et al., 2024).

Collectively, these findings highlight that behavioural and cultural contexts are critical determinants of fortification success. Effective communication strategies must therefore address sensory concerns and cultural misconceptions, while emphasising the health benefits of fortified products in locally resonant ways. Engaging community leaders, household cooks, and family decision-makers can promote trust and normalise the use of fortified bouillon cubes and other fortified foods within everyday diets in Ghana and similar low-resource settings.

2.6 Bouillon Cubes: An Innovative Fortification Vehicle

Bouillon cubes are a widely consumed dietary staple across West Africa and serve as a practical vehicle for delivering essential micronutrients to large populations. Their centralised production enables uniform fortification and scalable distribution, making them

particularly effective for addressing micronutrient deficiencies (Matthias et al., 2022). In Northern Ghana, 99% of households regularly use bouillon cubes, with 77% consuming them at least twice daily, highlighting their potential as a fortification vehicle (Kumordzie et al., 2021).

Since the 1990s, some bouillon brands in West Africa have incorporated iodized salt, with voluntary fortification of iron and vitamin A introduced by certain companies (Klassen-Wigger et al., 2018). Studies demonstrate the efficacy of these fortified products in improving nutrient intake. For instance, in Senegal, iodine-fortified bouillon cubes could provide 7% to 115% of the recommended daily iodine intake depending on the iodine content (Spohrer et al., 2015). In northern Ghana, a study found that around two-thirds of dietary iodine intake among schoolchildren aged 6 to 13 years came from iodine-fortified bouillon cubes (Abizari, Dold, et al., 2017). Similarly, vitamin A-fortified bouillon cubes in Cameroon were predicted to reduce the prevalence of inadequate vitamin A intake among women and children without increasing the risk of excessive intake, complementing other intervention programmes (Engle-Stone et al., 2014).

Bouillon fortification with multiple micronutrients, including iron, zinc and vitamin A holds promise for reducing micronutrient deficiencies. In Burkina Faso, a modelling study of fortified cubes showed decreased inadequate intake of vitamin A by 30%, vitamin B12 by 38%, folate by 26%, and zinc by 13% (Adams et al., 2024). Additionally, replacing regular salt with iodized salt in bouillon cubes increased iodine intake by up to 56% of the Nutrient Reference Value per day while iron fortification contributed 3% to 40% depending on usage (Eilander et al., 2023).

Despite these potential successes, the high sodium content of bouillon cubes remains a public health concern, particularly in countries like Ghana with high a hypertension prevalence (Archer et al., 2022; Kumordzie et al., 2021). Sodium reduction strategies, such as gradual reductions in fortified products, have been shown to maintain consumer acceptance while preserving their nutritional value (Archer et al., 2022). While homemade condiments offer lower-sodium options, commercially fortified cubes ensure standardised nutrient delivery. Public health campaigns can promote fortified bouillon cubes while educating consumers on balancing nutritional benefits with sodium intake.

2.7 Theoretical Framework

This study uses two well-established theoretical frameworks: the Health Belief Model (HBM) and the Theory of Planned Behaviour (TPB). Together, these frameworks provide a robust and multidimensional approach to understanding the factors that shape the perceptions and acceptance of micronutrient-fortified bouillon cubes among non-enrolled household members in northern Ghana.

2.7.1 The Health Belief Model (HBM) in the Context of Nutrition Interventions

The Health Belief Model (HBM) is a foundational theoretical framework in public health that explains health behaviours through individual perceptions (Rosenstock, 1974). Originally developed to understand why individuals might not adopt preventive health measures, the HBM has been adapted to a variety of contexts, including nutrition interventions in low- and middle-income countries (LMICs) (Anuar et al., 2020; Beressa et al., 2024; Naghashpour et al., 2014; Nelson et al., 2021).

Central to HBM are its core constructs, which provide a structured lens to examine how perceptions influence behaviour. These constructs include:

1. **Perceived Susceptibility:** The belief about the likelihood of experiencing a health issue.
2. **Perceived Severity:** The belief regarding the seriousness of a health problem and its potential consequences.
3. **Perceived Benefits:** The perceived advantages of adopting specific behaviour, such as the health benefits associated with using fortified bouillon cubes.
4. **Perceived Barriers:** The factors that hinder behaviour change, which in this context include misconceptions about side effects, cost concerns, and resistance to new practices.
5. **Cues to Action:** External or internal triggers that motivate health-related actions, such as health education campaigns or endorsements from community leaders.
6. **Self-Efficacy:** The confidence in one's ability to perform the behaviour successfully.

In the present study, HBM is employed to explore how these constructs, particularly perceived barriers and self-efficacy, influence the acceptance and consistent use of micronutrient fortified bouillon cubes. By examining individuals' beliefs about health risks, benefits, and obstacles, this approach offers valuable insights into the psychosocial determinants of nutritional behaviours and informs the development of targeted public health interventions.

2.7.2 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour builds on the HBM by incorporating subjective norms and perceived behavioural control, thereby highlighting external social pressures and intentions. This is critical in communal contexts, such as Ghana, where family dynamics and cultural norms strongly influence food choices (Lee et al., 2023; McDermott et al., 2015; Sajjad et al., 2023). Proposed by Ajzen (1991), TPB suggests that three primary constructs, namely attitudes, subjective norms, and perceived behavioural control, determine an individual's intentions and behaviours (Ajzen, 1991):

Attitudes: This refers to an individual's beliefs about the benefits or drawbacks of a behaviour.

Subjective Norms: These are the social pressures or expectations from family, peers, or community members that influence behaviour.

Perceived Behavioural Control: This construct captures an individual's perception of their ability to perform a behaviour, influenced by external factors such as accessibility and affordability.

Theory of Planned Behaviour is particularly useful in this study for analysing how social expectations and practical challenges influence behavioural intentions and the actual use of fortified foods.

2.7.3 Significance of the Framework

The dual application of the HBM and TPB ensures a holistic analysis of the acceptance of fortified bouillon cubes by accounting for both individual and communal factors. This integrated approach provides a comprehensive understanding that will guide the

development of effective and culturally tailored interventions to improve health outcomes through enhanced nutrition strategies in resource-limited settings.

2.8 Perception and Acceptance for the Success of Nutrition Interventions

Understanding the perceptions and acceptance of fortified foods is important for the success of nutrition interventions in Ghana. Positive attitudes towards micronutrient fortification among Ghanaian parents, caregivers, and women of reproductive age may be driven by perceived health benefits, sensory attributes, cultural alignment, and economic accessibility. Enhancers of child health, such as increased appetite and reduced illness, serve as key drivers of acceptance (Adams et al., 2018; Kyei-Arthur et al., 2020). Sensory factors, including taste, texture, and appearance, also significantly influence acceptance, particularly for widely used products like fortified bouillon cubes (Creed-Kanashiro et al., 2016; Field et al., 2017; Wessells et al., 2023). Furthermore, cultural alignment with traditional dietary practices facilitates acceptance, as showed by high caregiver approval of interventions that integrate seamlessly into local culinary habits (Bechoff et al., 2023; Chadare et al., 2019).

Empirical studies in Ghana, such as those by Adams et al. (2018) and Wessells et al. (2024), report high acceptance rates for fortified foods, including fortified bouillon cubes. Wessells et al. (2024) documented that 93.8% of participants indicated they liked or were willing to continue using the fortified bouillon cubes during a two-week home trial, highlighting strong sensory satisfaction. However, reliance on short trial durations raises concerns about long-term sustainability. Moreover, acceptance is not a simply binary but may vary depending on the product formulation. For instance, higher iron levels could

reduce acceptability if they alter the taste, colour, or appearance of the food (Hurrell, 2021). Similarly, Adams et al. (2018) reported high household acceptance of small-quantity lipid-based nutrient supplements, especially among mothers, highlighting the importance of involving key household members in implementation.

These limitations emphasise the need for longitudinal mixed-methods research to capture the dynamic evolution of perceptions and acceptance over time. Integrating quantitative metrics with qualitative insights into cultural norms and sensory preferences can provide a nuanced understanding of how health benefits, affordability, and sociocultural factors shape behaviour. This approach is essential for designing interventions that are not only effective but also culturally appropriate and sustainable, ensuring long-term public health impact in combating micronutrient deficiencies.

2.9 Household Dynamics and Nutritional Interventions

Household dynamics are critical determinants of dietary choices and the success of nutritional interventions, particularly in resource-limited settings such as northern Ghana. Women's involvement in food preparation and caregiving plays a pivotal role, with greater decision-making power among women positively correlating with improved dietary diversity and nutritional outcomes. For example, households where women exercise significant control over food-related decisions often demonstrate higher acceptance of fortified foods and better child health outcomes, underscoring the importance of integrating gender empowerment into nutrition programmes (Zakariah-Akoto et al., 2021).

Socio-economic status (SES) further shapes access to nutritious foods and dietary diversity. Higher SES households in northern Ghana tend to exhibit better nutritional

outcomes due to increased affordability and accessibility of resources (Christian & Dake, 2022; Zakaria & Laribick, 2014). However, low-SES households often face affordability challenges, necessitating targeted interventions that address economic constraints while respecting cultural preferences.

Caregiver education significantly enhances dietary diversity and child nutrition outcomes by enabling optimal feeding practices, healthcare access, and effective integration of nutrition interventions. Bhutta et al. (2013) demonstrated that educated caregivers amplify the impact of fortification programmes through greater understanding and acceptance of fortified foods, leading to improved child growth and micronutrient status (Bhutta et al., 2013).

Cultural norms, including food taboos and traditional dietary practices, profoundly influence the acceptance of fortified foods (Zakariah-Akoto et al., 2021). For example, interventions aligned with local culinary habits tend to receive higher community approval. However, intra-cultural variations and resistance rooted in misconceptions highlight the need for targeted engagement with community leaders to ensure effective cultural tailoring (Mkandawire et al., 2022).

Studies in Ghana reinforce these dynamics. For instance, Essilfie (2024) demonstrated that households with women holding greater decision-making authority had better food security and child nutritional outcomes, indicating higher acceptance of fortified foods among women of reproductive age (Essilfie et al., 2024). Similarly, an evaluation of the Ghana School Feeding Programme found that children from households with higher education levels and income benefitted more, as these households could better complement the meals provided (World Food Programme, 2019). Nevertheless, significant

barriers persist. Economic constraints and deeply rooted cultural beliefs often limit the adoption of fortified foods, highlighting the need for sustained support and culturally appropriate resources (Christian & Dake, 2022).

Despite these insights, several limitations remain. Most studies rely on cross-sectional designs, limiting the ability to evaluate long-term impacts of nutritional interventions. Additionally, research frequently underrepresents low-SES households, leaving critical gaps in understanding how affordability and accessibility influence outcomes. Future research should adopt longitudinal approaches and inclusive sampling strategies to capture the evolving dynamics of household decision-making. Furthermore, a stronger focus on women's empowerment, combined with culturally sensitive interventions, is essential to enhance the effectiveness and sustainability of nutritional programmes.

2.10 Gaps in Literature

Existing research on fortified foods often prioritises direct intervention participants, such as caregivers or enrolled individuals, while neglecting the broader household dynamics that critically influence the acceptance and sustained use of fortified foods. This narrow focus overlooks the perspectives of non-enrolled (non-index) household members, whose behaviours and attitudes can significantly shape intervention outcomes. Additionally, the reliance on short-term studies limits our understanding of long-term sustainability and adherence to fortified food use, an essential factor in addressing persistent MNDs.

A key gap also exists in linking household behavioural factors to the health outcomes of food fortification interventions. This gap is particularly relevant for programmes that position households as the entry point for improving nutrition. Gaining a

comprehensive understanding of how household decision-making, cultural norms, and socio-economic factors influence micronutrient outcomes is essential for designing effective and scalable interventions.

This study aims to address these gaps by exploring the perceptions and acceptance of micronutrient-fortified bouillon cubes among non-index household members of women and children participating in a randomised controlled trial in Northern Ghana. By examining these perspectives over an extended intervention period, the study seeks to uncover household-level dynamics and provide valuable insights into the long-term viability of fortified food interventions.



PART TWO: OBJECTIVES AND METHODS



CHAPTER THREE

STUDY OBJECTIVES

3.1 Main Objectives

The primary objectives of this study were:

1. To explore the perceptions (opinions and attitudes) and acceptance of the study-supplied bouillon cubes provided for household cooking in the CoMIT Project intervention trial among non-index household members (NIHMs) of the WRA and PSC enrolled in the trial.
2. To assess whether the perceptions and acceptance of the study-supplied bouillon cubes among the NIHMs were associated with the haemoglobin and spot urinary iodine concentrations of the WRA and PSC enrolled in the trial.

3.2 Specific Objectives

The specific objectives were to:

1. develop and validate a questionnaire for measuring household perceptions and acceptance of micronutrient-fortified bouillon cubes.
2. determine whether the perception and acceptance of the study supplied bouillon cubes among the NIHMs changed over time (i.e., from within the first two months after receiving the bouillon intervention to within the last two months before exiting the intervention).
3. determine the individual- and household-level factors associated with the acceptance of the study bouillon cubes at the two time points, namely within the

first two months after receiving the bouillon intervention and within the last two months before exiting the intervention.

4. explore the drivers of and barriers to the acceptance of the study bouillon cubes among the NIHM
5. evaluate the association between the perception or acceptance of fortified bouillon cubes among NIHM and the haemoglobin and spot urinary iodine concentrations of WRA and PSC enrolled in the primary CoMIT trial.
6. explore whether the association between the perception or acceptance of fortified bouillon cubes among NIHM and the haemoglobin and spot urinary iodine concentrations of WRA and PSC enrolled in primary CoMIT trial was modified by household characteristics, namely:
 - a) Sex of household head
 - b) Age of household head
 - c) Educational level of household head
 - d) Household assets index (Socio-economic status)
 - e) Household food insecurity access scale (HFIAS) score
 - f) Number of household members
 - g) Household bouillon consumption (grams per capita per day)

These specific objectives have been organized into three main manuscripts in the results section. These include:

1. Development and validation of a questionnaire to assess perceptions and acceptance of micronutrient-fortified bouillon cubes in northern Ghana.

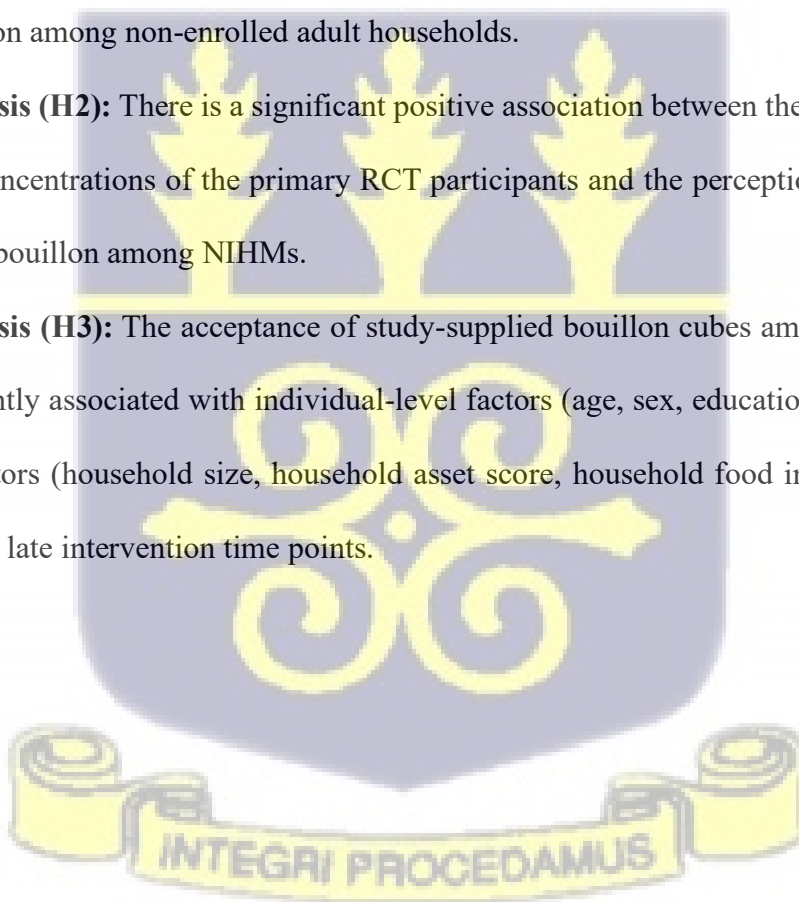
2. Perception and acceptance of micronutrient-fortified bouillon cubes among NIHMs of women and children in a Randomised Trial in northern Ghana.
3. Randomised trial of fortified bouillon cubes in northern Ghana: associations of the perception and acceptance of the study bouillon cubes among NIHMs with the haemoglobin and iodine status of trial participants.

3.3 Hypothesis

Hypothesis (H1): There is a significant positive association between the haemoglobin and iodine concentrations of the primary RCT participants and the perception and acceptance of bouillon among non-enrolled adult households.

Hypothesis (H2): There is a significant positive association between the haemoglobin and iodine concentrations of the primary RCT participants and the perception and acceptance of study bouillon among NIHMs.

Hypothesis (H3): The acceptance of study-supplied bouillon cubes among the NIHMs is significantly associated with individual-level factors (age, sex, education) and household-level factors (household size, household asset score, household food insecurity score) at early and late intervention time points.



CHAPTER FOUR

METHODS

This section is organised into two parts. The first provides a brief description of the CoMIT Project RCT and the study settings. The second outlines the current study, including its design, participant recruitment, data collection procedures, the data extracted from the index participants (spot urinary iodine concentration and haemoglobin concentrations), and an overview of the statistical analyses.

4.1 CoMIT Intervention Overview

The CoMIT project evaluated the effect of household use of bouillon cubes fortified with multiple micronutrients (iodine, vitamin A, folic acid, vitamin B₁₂, iron, and zinc) versus iodine-only cubes on haemoglobin (Hb) concentrations and selected micronutrient biomarkers among non-pregnant, non-lactating women of reproductive age (WRA, 15–49 years; n = 1,028), pre-school children (PSC, 2–5 years; n = 690), and on breast milk micronutrient concentrations in lactating women (LW, 4–18 months postpartum; n = 690). Detailed methods are reported elsewhere (Engle-Stone et al., 2024).

Briefly, CoMIT was a double-blind, community-based randomised controlled trial conducted across 16 Ghana Statistical Service-defined sites in the Kumbungu and Tolon districts of northern Ghana, covering 14 urban and 14 rural (rural and semi-urban) areas. The intervention lasted nine months for WRA and PSC, and three months for LW. Randomisation occurred at the household level using a computer-generated block design (block sizes of 4 or 8). Participants drew group assignments from opaque, numbered envelopes linked to study codes. To maintain blinding, bouillon cubes were identically

packaged and labelled with three-digit alphanumeric codes, with no indication of nutrient content. Allocation codes were managed independently by the University of Ghana and the University of California, Davis.

Eligibility for index participants required the absence of severe illness, capacity to provide consent, and planned residence in the study area throughout the trial period. For WRA, additional criteria included a negative malaria rapid diagnostic test, C-reactive protein (CRP) < 5 mg/L at the radial immunodiffusion (RID) screening, and Hb $\geq$ 80 g/L at both screening and baseline. Pre-school children were eligible if they had a mid-upper arm circumference (MUAC) $\geq$ 11.5 cm at recruitment, Hb $\geq$ 70 g/L, a weight-for-height z-score (WHZ) $\geq$ -3 SD, and no signs of bilateral pitting oedema at baseline. Lactating women were eligible if they were 4–18 months postpartum. Households were eligible if they agreed to use only the study bouillon cubes, had no known allergies to the ingredients, and were not enrolled in another study.

Participants were recruited through door-to-door visits using a random-walk approach conducted by trained fieldworkers in collaboration with local health workers. Multiple eligible participants from different physiological groups could be enrolled within a single household. Household heads provided oral consent, after which written informed consent (or thumbprint) was obtained from eligible adults. Caregivers provided consent for PSC, and adolescents aged 15–17 years provided assent in addition to caregiver consent.

Following baseline assessments, households were assigned to receive either micronutrient-fortified or iodine-only bouillon cubes. Fortified cubes contained vitamin A (200 μ g), folic acid (80 μ g), vitamin B₁₂ (1.2 μ g), iron (4 mg as ferric pyrophosphate), zinc (3 mg as zinc oxide), and iodine (30 μ g as potassium iodate). Control cubes contained only

iodine (30 µg). Cubes were distributed fortnightly based on household size and estimated consumption. Participants were instructed to use only the study cubes in cooking. Adherence was monitored through spot checks and structured questionnaires.

Ethical approvals were obtained from the Ghana Health Service Ethics Review Committee (GHS-ERC ID: 024/11/21), the University of California, Davis (IRB ID: 1837253), and the Ghana Food and Drugs Authority (Certificate No. FDA/CT/2213[1]). The trial was registered at ClinicalTrials.gov (NCT05178407) and the Pan-African Clinical Trials Registry (PACTR202206868437931).

4.2 Study Setting

The study was conducted in the Tolon and Kumbungu districts in the Northern Region of Ghana, located approximately 30 kilometres east of the regional capital, Tamale. These districts were chosen for their high prevalence of micronutrient deficiencies and high consumption of bouillon cubes, making them an ideal setting for evaluating micronutrient-fortified bouillon cube interventions (Kumordzie et al., 2021; UNICEF, 2017).

The population was predominantly engaged in subsistence farming, with dietary practices characterised by limited diversity and a heavy reliance on staple foods such as millet, sorghum, and groundnuts (Abizari, Azupogo, et al., 2017; Kumordzie et al., 2021).

The districts generally had access to essential public amenities, including health centres, tarmacked roads, and mobile communication networks. Geographically, Tolon and Kumbungu are adjoining districts sharing boundaries with West Mamprusi, Central Gonja, West Gonja, Savelugu/Nanton, and the Tamale Municipality (**Figure 1**).

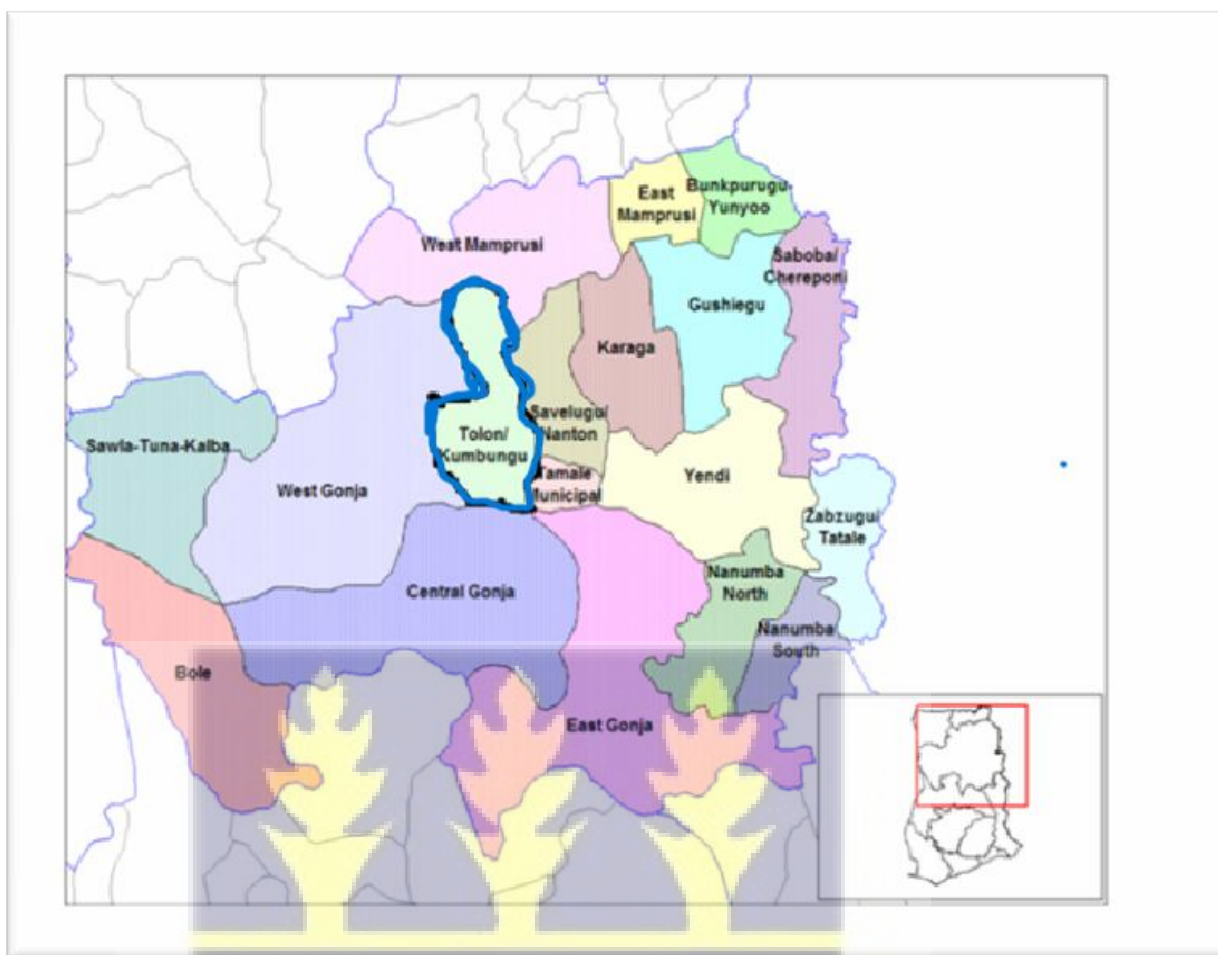


Figure 1. Map of the northern region highlighting the district of Tolon and Kumbungu

THE PERCEPTION AND ACCEPTANCE OF MICRONUTRIENT-FORTIFIED BOUILLON CUBES AMONG HOUSEHOLD MEMBER STUDY

4.3 Study Design

This study was nested within the CoMIT project. The study used a longitudinal mixed-methods design, combining three quantitative surveys and one round of focus group discussions (FGDs). The quantitative surveys primarily focused on measuring changes in perceptions and acceptance, while the FGDs explored an in-depth understanding of perceptions and acceptance of the study-supplied bouillon cubes (Creswell & Creswell,

2017; Guetterman & Fetters, 2018). The mixed-methods approach was designed to ensure methodological triangulation, thereby enhancing reliability through cross-validation of findings from different data sources (Tashakkori & Teddlie, 2021).

The study data collection was structured as follows:

1. **Pre-Intervention (T0) quantitative data:** Data were collected within three weeks after enrolment into the trial study to capture household and individual characteristics.
2. **Early Intervention (T1) quantitative data:** Data were collected within the first two months after households received the study-supplied bouillon cubes to assess initial perceptions and acceptance during household cooking.
3. **Midpoint data:** Focus group discussions were conducted five months into the trial study to explore factors (drivers and barriers) influencing perceptions and acceptance of the study-supplied bouillon cubes.
4. **Late Intervention (T2) quantitative data:** Data were collected within the final two months of the 9-month intervention to capture longer-term changes in perceptions and acceptance of the study-supplied bouillon cubes.

4.4 Participants and inclusion and exclusion criteria

Participants were non-index household members (NIHMs) aged ≥ 15 years who shared households with index participants enrolled in the main CoMIT RCT. Specific eligibility criteria included: (i) residing in the household for at least one month prior to enrolment, (ii) intending to remain in the household throughout the trial period, and (iii) providing written informed consent (or assent with caregiver consent for those aged 15–17 years).

Participants were excluded if they had: (i) individuals with known allergies to ingredients in the bouillon cubes or sensory-related medical conditions (e.g., synaesthesia).

4.5 Fieldworker Training

Fieldworkers for this study were part of the CoMIT Trial team. Five recruiters, each holding a first degree in Nutrition or the Social Sciences, underwent a one-month training focused on recruitment procedures and study methodologies. Additionally, ten survey data collectors received one week of intensive training on interpreting Likert-scale questions and administering the study-specific questionnaire using SurveyCTO on tablets.

Practical sessions were conducted during both the early and late intervention phases. These included role plays and field-based exercises held in a community demographically similar to the study sites in Tamale. During the late phase, four additional data collectors received five days of training focused on administering Likert-scale items. Three fieldworkers fluent in Dagbani also underwent one week of training in the facilitation of focus group discussions, with an emphasis on practical application.

To support effective data collection, study materials were translated into Dagbani by the field team and back-translated into English by two independent bilingual individuals. Discrepancies were resolved collaboratively to ensure consistency and accuracy. Competency assessments were conducted at the end of each training phase, and regular supervision and feedback sessions were implemented throughout data collection to ensure data quality.

4.6 Participant Recruitment

Non-index household members were recruited between January and June 2023, during the three-week observation period of the trial. This period spanned from the day of recruitment to the day of baseline assessment of the index participant. All households enrolled in the CoMIT RCT were included in this study, and no sampling of households was performed. Household rosters compiled during index participant recruitment were used to identify eligible NIHMs. In households with a single eligible NIHM, that individual was automatically enrolled. In households with two or more eligible NIHMs, one was randomly selected using a Kish table (Nemeth, 2002). If a selected NIHM declined, another was randomly selected using the same procedure if more than one eligible alternative remained. If only one eligible individual remained, that person was selected.

Purposive sampling was used to select participants for the FGDs. Discussions were stratified by sex and conducted separately for men and women to allow for free expression of gender-specific perspectives. Age and household cube code were also considered in the sampling process. Participants were categorised into two age groups (<50 years and ≥ 50 years), with balanced representation across groups. Each FGD included individuals representing all four cube codes used in the intervention to capture diverse user experience.

Recruitment was carried out by five trained interviewers fluent in both English and Dagbani, and they were supervised by field supervisors to ensure adherence to ethical standards and protocols. Given that many participants had limited literacy in Dagbani, the participant information sheets and questionnaires were provided in English, with on-site translations as needed. Interviewers explained the study procedures in detail, answered questions, and obtained informed consent via signature or thumbprint. Comprehension of the study was assessed by asking each participant five key questions, and any

misunderstandings were clarified before enrolment. Each participant was assigned a unique identifier that was linked to the corresponding index participant in their household. Of all eligible NIHM, six declined participation due to uncertainty about their availability, while the remaining individuals were successfully enrolled.

4.7 Sample Size Determination

The sample size for this study was determined by the total number of households enrolled in the CoMIT RCT. One NIHM was recruited per household, regardless of the number or combination of index participants (WRA, PSC, and LW) present. Although the RCT enrolled 1,028 WRA, 690 PSC, and 690 LW, these participants may have come from the same household. Therefore, assuming that all three physiological groups could be represented within a single household, the minimum number of households required would be 1,028. The actual number could be higher if some households included only one or two index participants. This number also reflected the maximum potential sample size for the present study.

At T0, 1,047 participants were recruited from households representing all three index participant groups. Following pre-intervention (T0), data collection at early intervention (T1) and late intervention (T2) focused exclusively on households with WRA and PSC participants. Households recruited solely on the basis of the presence of an LW participant were excluded from T1 and T2, as their eligibility was limited to the first three months of the intervention. Consequently, 731 participants were included at T1 and 796 at T2. The variation in sample size across time points reflects differences in participant

availability. Some participants who were unavailable during T1 were present at T2, resulting in a slight increase in participation.

A post hoc power analysis was conducted using a paired-sample design to assess within-subject changes in perception scores between T1 and T2. Assuming a small-to-moderate effect size (Cohen's $d_z = 0.26$), a significance level of 0.05, and 80% power, the minimum required sample size was 119 participants. In comparison, detecting the same effect size in a between-group design (Cohen's $d = 0.26$) would have required 396 participants (198 per group) (Cohen, 2013). Given that the observed sample sizes at T1 ($n = 731$) and T2 ($n = 796$) greatly exceeded both design thresholds, the study was sufficiently powered to detect meaningful within- and between-group differences in perception and acceptance scores over time.

For the qualitative component, 24 FGDs were conducted, with each group comprising 5 to 8 participants. The number of FGDs was determined using the principle of information power (Malterud et al., 2016). Recruitment for the FGDs was structured to ensure equal representation across all the study cube codes used for randomisation.

4.8 Development of Study Questionnaire

The study's quantitative questionnaire for perceptions and acceptance and the FGD guide were developed using the Health Belief Model (Rosenstock, 1974) and Theory of Planned Behaviour (Ajzen, 1991) to capture participants' perceptions (opinions and attitudes) and acceptance of bouillon cubes. A literature review informed the creation of questions addressing sensory attributes, ease of use, beliefs, benefits (social, economic, cultural and health) and preferences. Input from the CoMIT Team, comprising experts in nutrition, public health, and consumer behaviour, further refined the tools.

The questionnaire was pre-tested with 18 adult household members from communities similar to the study sites to assess clarity, relevance, and cultural appropriateness. Feedback from the pre-test informed refinements, ensuring the tools were well-aligned with the study's objectives.

4.9 Data Collection

4.9.1 Data Collection Procedure

Data collection was conducted from January 2023 to June 2024 using structured questionnaires and FGD guides. SurveyCTO software on tablets was used to capture quantitative data, ensuring accuracy and efficiency.

4.9.2 Quantitative Data Collection

The quantitative assessment was conducted across three time points (T0, T1, and T2). A structured questionnaire comprising three categorical items and ten items rated on a 5-point Likert scale (ranging from 1 = completely disagree to 5 = completely agree, with an additional 'not applicable' option) was used to validate the tool measuring perceptions of bouillon cube usage.

At T1 and T2, participants completed questionnaires specifically designed to assess the study-supplied bouillon cubes. These questionnaires included 26 items rated on a 5-point Likert scale (ranging from 1 = completely disagree to 5 = completely agree, with an additional 'not applicable' option) and three categorical items. Identical questions were administered at T1 and T2 to facilitate comparisons and analyse shifts in perception and

acceptance resulting from the intervention. This approach also allowed for the identification of any habitual changes over time.

4.9.3 Socio-Demographic Data Collection

Socio-demographic data were collected during at T0. Information included age, sex, education, occupation, religion, ethnicity, cooking role within the household, relationship to the household head, and household composition. These data served as covariates and predictors for the study.

4.9.4 Qualitative Data Collection

Twenty-four FGDs were conducted across 12 study sites to explore drivers and barriers related to perceptions and acceptance of the study bouillon cubes. Discussions were held in community centres and classrooms on weekends, guided by a pre-tested topic guide (see **Supplementary material 1** Appendix). Themes included nutritional and health benefits, sensory attributes, ease of use, cultural integration, and overall acceptance. Three trained facilitators fluent in Dagbani conducted the sessions, which were audio-recorded, with non-verbal cues documented.

4.9.5 Data Collected in the Parent Prial

Data extracted from the CoMIT database provided household information, as well as Hb levels and spot urinary iodine concentration (UIC) measured at baseline and endline for the index participants. Household-level data included household size (number of household members), household asset scores (socio-economic status), and the sex, age, education, and occupation of household heads. Baseline household bouillon consumption (g/day) was

calculated by dividing the total grams used per day by the household size, yielding the per capita daily intake (g/day). Household Food Insecurity Access Scale (HFIAS) scores were also computed (Coates et al., 2007). Additional demographic information, including the marital status and age of WRA, as well as the sex and age of PSC, was extracted to support the analysis of household and individual characteristics.

4.10 Outcome variables

The primary outcome variables include:

1. Perception scores (perception composite scores), which quantified the opinions and attitudes of NIHMs toward the use of study bouillon cubes at T1 and T2.
2. Acceptance scores (acceptance composite scores), which measured the extent to which NIHMs accepted the study bouillon cubes at T1 and T2.
3. Haemoglobin concentration, measured in grams per decilitre (g/dL), reflecting the combined influence of iron, folate, and vitamin B12 status among WRA and PSC at baseline and endline.
4. Spot urinary iodine concentration (UIC), measured in micrograms per litre ($\mu\text{g/L}$), reflecting iodine status among WRA and PSC at baseline and endline.

The secondary outcome variable included qualitative data from FGDs. These data helped explain factors influencing perception and acceptance of the study-supplied bouillon cubes and complemented the quantitative findings in evaluating the intervention's impact.

4.11 Data Processing and Statistical Analysis

The statistical analyses for this thesis were designed to address the research objectives through a combination of quantitative and qualitative methods.

The perception and acceptance composite scores were calculated through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). Exploratory factor analysis was used to identify the underlying factor structure, followed by CFA to assess the model's fit and validity. Reliability was assessed using Cronbach's alpha. Composite scores for perception and acceptance were computed by weighting each item with its CFA-standardised factor loading and summing these values to produce normalised scores.

To validate the developed questionnaire assessing perceptions (opinions and attitudes) toward bouillon cubes used in the household, EFA and CFA were conducted to evaluate construct validity and model fit. Internal consistency was further assessed using Cronbach's alpha.

To analyse changes in NIHMs' perceptions and acceptance scores of the study-supplied bouillon cubes over the intervention period, Bayesian linear mixed-effects models were used. These models estimated temporal changes while accounting for repeated measures and individual variability. Household- and individual-level factors associated with perceptions and acceptance scores were also examined using the same approach.

Associations between NIHMs' perceptions or acceptance and index participants' Hb (g/dL) and spot UIC ($\mu\text{g/L}$) were assessed using two modelling approaches. Generalised Estimating Equations (GEEs) were used to model the relationship with Hb, and Generalised Additive Mixed Models (GAMMs) were applied for UIC, accounting for repeated measures. To assess effect modification by household-level factors, interaction

terms between perception or acceptance scores and variables such as food insecurity and socio-economic status and household head demographics were included in both models.

Qualitative data from the FGDs were analysed using thematic analysis following Braun and Clarke's six-step framework (Braun & Clarke, 2006), complemented by Latent Dirichlet Allocation (Blei et al., 2003) to identify dominant themes and patterns related to the sociocultural, sensory, economic, and health factors that act as drivers and barriers to perception and acceptance.

The quantitative and FGD data were analysed separately and later integrated during the discussion phase to assess perception and acceptance of the study-supplied bouillon cubes. Statistical analyses, including methods, models, and interpretations, are presented under each research objective in part three.

4.12 Ethical Considerations

The study was part of a larger randomised controlled trial, the CoMIT project. Ethical clearance was obtained from the Ghana Health Service Ethical Review Committee (GHS-ERC ID: 024/11/21), the University of California, Davis (IRB ID: 1837253), and the Ghana Food and Drugs Authority (Certificate No. FDA/CT/2213[1]). Permissions were obtained from the Regional (Northern Region) and District (Tolon and Kumbungu) Directors of Health Services, as well as community leaders, before participant recruitment. Informational meetings were conducted with community leaders to explain the study's objectives, methods, and potential benefits to participants and communities. Informed consent was obtained from all participants after the study procedures were explained to them.

PART THREE: RESULTS



CHAPTER FIVE

SPECIFIC OBJECTIVE ONE

Development and Psychometric Validation of a Questionnaire assessing Perception and Acceptance of Micronutrient-Fortified Bouillon Cubes among Non-Index Household Members Aged ≥ 15 Years in Northern Ghana

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Abstract

Background and objective: Micronutrient deficiencies remain a major public health issue in West Africa, contributing to anaemia, impaired cognitive development, and increased infection risk. Bouillon cubes, widely consumed in the region, offer a culturally appropriate means of micronutrient delivery. However, no validated instrument exists to assess the psychosocial and behavioural factors influencing household acceptance of fortified bouillon cubes. This study aimed to develop and validate a questionnaire to assess perceptions and acceptance of micronutrient-fortified bouillon cubes among non-index household members (NIHMs) in northern Ghana.

Methods: A 29-item questionnaire was developed based on the Theory of Planned Behaviour and Health Belief Model. The development process included a literature review, expert evaluations, and pre-testing with 18 adults for translational validity. The instrument comprised 26 five-point Likert-scale items and 3 categorical preference items. One NIHM aged ≥ 15 years was randomly selected from each consenting household using a Kish table. Subsequently, the questionnaire was administered to 731 NIHMs within two months of the intervention initiation as part of a nine-month, double-blind, randomised controlled trial. This trial compared multiple micronutrient-fortified bouillon cubes (containing vitamins

A, B₁₂, folic acid, iron, zinc, and iodine) to iodine-only bouillon cubes in the Kumbungu and Tolon districts of northern Ghana. The sample was randomly divided into exploratory (n = 292) and confirmatory (n = 439) subsets. Reliability was assessed using Cronbach's alpha and composite reliability, while construct validity was evaluated via average variance (AVE) extracted. All analyses were performed using R (v 4.3.1).

Results: Participants had a mean age of 40.8 ± 17.4 years, with 58.8% being female. Exploratory factor analysis identified two constructs: Perception (8 items) and Acceptance (11 items), which together explained 56% of the variance. Confirmatory factor analysis retained 18 items (Perception = 8; Acceptance = 10) and showed good model fit (chi-square/df = 1.91, root mean square error of approximation [RMSEA] = 0.04, comparative fit index [CFI] = 0.98, Tucker–Lewis index [TLI] = 0.98, and standardised root mean square residual [SRMR] = 0.06). Internal consistency was acceptable, with Cronbach's alpha values of 0.71 for Perception and 0.72 for Acceptance. Composite reliabilities were 0.86 for Perception and 0.82 for Acceptance. Convergent validity was acceptable for Perception (AVE = 0.52) and marginal for Acceptance (AVE = 0.46). Discriminant validity was supported, and the correlation between the Perception and Acceptance constructs was moderate ($r = 0.45$), indicating related but distinct dimensions.

Conclusion: The validated 18-item questionnaire demonstrates strong psychometric properties for assessing perceptions and acceptance of micronutrient-fortified bouillon cubes. It provides a standardised tool to guide the design, implementation, and evaluation of fortification programmes and can be adapted for other fortified foods in similar settings.

Keywords: Micronutrient deficiencies, fortified bouillon cubes, perceptions and acceptance, questionnaire validation, Ghana

Introduction

Micronutrient deficiencies (MNDs), commonly referred to as hidden hunger, remain a widespread public health challenge, particularly affecting women of reproductive age and pre-school children in West Africa (Stevens, Paciorek, et al., 2022; WHO, 2024a). These deficiencies contribute significantly to anaemia, impaired cognitive development, and increased vulnerability to infections (Mao et al., 2024; WHO, 2024c). In the northern regions of Ghana, dietary reliance on nutrient-poor staples, compounded by socio-economic constraints, continues to sustain high rates of MNDs (Petry et al., 2021; UNICEF, 2017; Wegmüller et al., 2020).

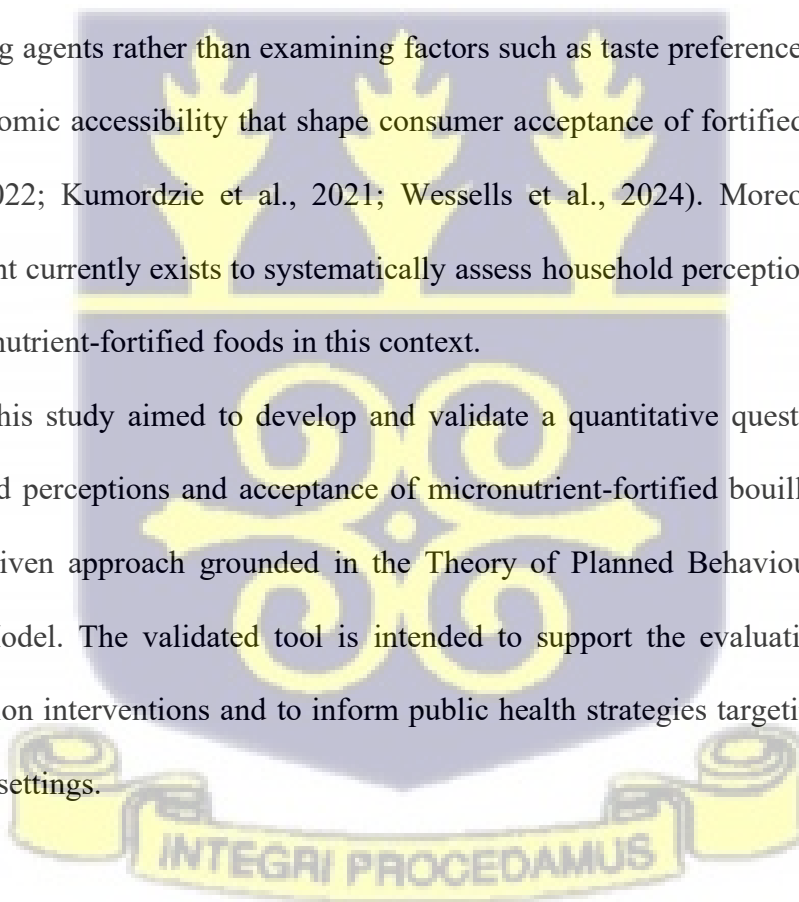
Large-scale food fortification is a proven strategy to mitigate MNDs and has demonstrated population-level benefits in low- and middle-income countries (Olson et al., 2021; Rohner et al., 2023; UNICEF, 2024). However, in Ghana, the implementation of fortification initiatives has been constrained by regulatory challenges and inadequate household uptake (Nyumuah et al., 2012; UNICEF, 2017). Bouillon cubes, consumed regularly by nearly all households across different socio-economic groups, represent a culturally familiar and feasible vehicle for micronutrient delivery (Abizari, Dold, et al., 2017; Adams et al., 2024; Engle-Stone et al., 2021; Kumordzie et al., 2021; Moretti et al., 2018). They offer the advantage of requiring minimal behavioural change in food preparation practices (Wessells et al., 2023).

Building on this premise, the Condiment Micronutrient Innovation Trial (CoMIT) conducted a community-based, double-blind, randomised controlled trial in the Kumbungu and Tolon districts of northern Ghana to assess the impact of multiple micronutrient-fortified bouillon cubes on nutritional status among women and children (Engle-Stone, Wessells, et al., 2024). Within households participating in this trial, key decisions regarding

food preparation, including the use of study-supplied bouillon cubes, are often influenced by non-index household members (NIHMs), such as household heads and primary cooks. Their perceptions and acceptance of fortified bouillon cubes are key determinants of the reliability and effectiveness of fortification interventions at the household level.

Despite the documented physiological benefits of food fortification (Duggal et al., 2022; Keats et al., 2019; Osendarp et al., 2018; Tchum et al., 2021; WHO, 2024b), there is a notable gap in research on the psychosocial and behavioural determinants that influence household-level adoption and sustained use of fortified foods (GAIN, 2023b; Geny et al., 2023; Rai et al., 2019). Existing studies in Ghana have largely explored bouillon cubes as flavouring agents rather than examining factors such as taste preferences, cultural beliefs, and economic accessibility that shape consumer acceptance of fortified versions (Archer et al., 2022; Kumordzie et al., 2021; Wessells et al., 2024). Moreover, no validated instrument currently exists to systematically assess household perceptions and acceptance of micronutrient-fortified foods in this context.

This study aimed to develop and validate a quantitative questionnaire to assess household perceptions and acceptance of micronutrient-fortified bouillon cubes, using a theory-driven approach grounded in the Theory of Planned Behaviour and the Health Belief Model. The validated tool is intended to support the evaluation and design of fortification interventions and to inform public health strategies targeting MNDs in low-resource settings.



Methods

Study design and setting

This questionnaire validation was conducted as a sub-study within the Condiment Micronutrient Innovation Trial (CoMIT). Briefly, CoMIT was a double-blind, community-based randomised controlled trial conducted at 16 sites in the Kumbungu and Tolon districts of the Northern Region of Ghana. The trial assessed the impact of household use of bouillon cubes fortified with multiple micronutrients (iodine, vitamin A, folic acid, vitamin B12, iron, and zinc) compared with control cubes fortified with iodine alone. Outcomes included haemoglobin levels and selected biomarkers among three groups of index participants: non-pregnant, non-lactating women of reproductive age; lactating women 4–18 months postpartum; and children aged 2–5 years.

Households were randomised using a computer-generated block design, and blinding was maintained through identical packaging. Bouillon cubes were distributed biweekly, based on household size, over a nine-month period.

Ethical approval was obtained from the Ghana Health Service Ethical Review Committee (GHS-ERC ID: 024/11/21), the Institutional Review Board at the University of California, Davis (IRB ID: 1837253), and the Ghana Food and Drugs Authority (Certificate No. FDA/CT/2213[1]). The trial was registered at ClinicalTrials.gov (NCT05178407) and the Pan-African Clinical Trials Registry (PACTR202206868437931). Detailed study protocols have been published elsewhere (Engle-Stone et al., 2023).

Study participants and recruitment

Participants in this sub-study were non-index household members (NIHMs) aged 15 years or older who regularly shared meals in a day with the index participant, were not enrolled in the main trial, and provided written informed consent. For those aged 15–17 years, assent was obtained in addition to parental consent or that of a caregiver. Individuals who declined to provide consent or assent were excluded. Following household consent and recruitment of the index participant, one NIHM was randomly selected per household using the Kish method (Nemeth, 2002), based on the household roster compiled during the recruitment of the index participant. Selecting one NIHM per household helped avoid intra-household response dependence, while random selection minimised selection bias and ensured that perspectives were captured from a diverse range of household members beyond household heads or primary cooks.

Theoretical Framework

The questionnaire was developed using the Theory of Planned Behaviour (TPB) and the Health Belief Model (HBM). TPB posits that behavioural intentions are influenced by attitudes, subjective norms, and perceived behavioural control (Ajzen, 1991). In this study, attitudes were measured through evaluations of sensory attributes (e.g., “You like the smell of the study bouillon cubes”) and overall satisfaction with meals prepared using the product (Caso et al., 2024; Srivastava et al., 2023). Subjective norms were assessed with items such as “You do not think your neighbours or friends would like the study bouillon cubes” and “You have good things to say about the study bouillon cubes.” Perceived behavioural control was evaluated using statements like “The study bouillon cubes can be used in your

household every day during the week” and “The study bouillon cubes can be used in your household any number of times in a day.”

Complementing TPB, the Health Belief Model (HBM) emphasises health-related beliefs, including perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy (Rosenstock, 1974). Perceived benefits were operationalised as willingness to continue using or purchasing the cubes, interpreted as a proximal indicator of value recognition, given that long-term health effects were not yet observable. Perceived benefits were captured with items such as “You want your household to use the study bouillon cubes in the future if they are available,” while perceived barriers were measured with items like “In the past month, you think your household should have purchased non-study bouillon cubes from the market.” Cues to action and self-efficacy were addressed through statements such as “You would be interested in buying the study bouillon cubes if they are sold in the future” and “Your household members have not observed any problems with using the study bouillon cubes.”

The use of this dual-framework approach enabled a comprehensive assessment of cognitive, social, and health-related factors influencing the acceptance and use of fortified bouillon cubes (Beressa et al., 2024; Glanz et al., 2015; Kroke & Ruthig, 2024; Yastica et al., 2020).

Questionnaire development and pretesting

A literature review was conducted to identify key constructs from the TPB and the HBM relevant to the adoption of micronutrient-fortified foods. The review focused on fortified products such as condiments, seasonings, rice, and complementary foods, examining

factors including flavour preferences, compatibility with traditional diets, cultural attitudes, and perceived health benefits (Adu-Afarwuah et al., 2008; Eilander et al., 2023; Geicu-Cristea et al., 2024; Verbeke, 2005; Wessells et al., 2024). Based on these domains, an initial pool of 33 items was generated. An interdisciplinary panel from the CoMIT research team, comprising experts in nutrition, public health, consumer behaviour, and statistics, evaluated the items for clarity and relevance. This process reduced the pool to 29 items. The instrument was forward-translated from English into Dagbani by two bilingual translators familiar with nutrition and public health terminology, and then back-translated into English by an independent translator who was blinded to the original version. Discrepancies between the two English versions were reviewed by the research team until conceptual and linguistic equivalence was achieved, consistent with recommended cross-cultural adaptation procedures (Beaton et al., 2000).

Translational validity was further assessed by pretesting the questionnaire with 18 adult household members (cooks, household heads, and formal workers aged 20–70 years) from two rural communities located approximately 15–20 km from the nearest main study sites. These communities were part of the intervention sites. They were chosen because they shared similar cultural and dietary practices but were excluded from the main data collection to prevent contamination. Participants were purposively recruited to represent household heads, primary cooks, and other adult household members. During the pretesting, participants evaluated the clarity and cultural appropriateness of the questionnaire. Feedback from this process prompted iterative refinements, including rewording several items for brevity, adjusting response options, and clarifying the scale definitions before finalisation.

The pretest sample size ($n = 18$) was sufficient for assessing face and translational validity, ensuring clarity and cultural appropriateness of items prior to large-scale validation. While adequate for identifying issues of comprehension and wording, the small pretest sample may not have captured subgroup-specific interpretations and was therefore not used for psychometric validation. Construct validity was subsequently examined in the full study sample through exploratory and confirmatory factor analyses.

The final questionnaire consisted of 26 items measured on a five-point Likert scale (1 = completely disagree to 5 = completely agree, with an additional ‘non-applicable’ option), two categorical items, and one binary item. The full validated instrument is provided as supplementary material (see **Supplementary material 1** in Appendix).

Data collection procedure.

Trained fieldworkers, who were instructed in study-specific ethical procedures, including avoiding leading questions, ensuring cultural sensitivity, and maintaining participant confidentiality, administered the questionnaire through face-to-face interviews using tablet-based data entry (SurveyCTO). Background information on participants, including age, sex, household cooking role, education, and occupation, was also recorded. Supervisors reviewed datasets daily to ensure data quality and adherence to the study protocol. Data collection occurred between March and September 2023, and for each household, the questionnaire was administered within the first two months after the household began receiving the bouillon intervention. Because data were collected at this early stage, long-term health effects of fortification could not yet be observed; responses

therefore reflect short-term perceptions and behavioural intentions rather than measurable health outcomes.

Data Processing and Analysis

Data were collected from 742 participants, and after excluding 11 incomplete or inconsistent responses, 731 valid responses remained for analysis. Prior to analysis, negatively framed items (Q13, Q14, Q15, Q23, Q25, Q27) were reverse scored to ensure consistent interpretation. Three categorical items were recoded to match the five-point Likert scale structure, enabling their inclusion in the factor analysis alongside the Likert-scale items.

Five items (Q8, Q9, Q15, Q21, Q22) were removed prior to factor analysis due to a lack of response variance, with over 95% of participants selecting the same response. Items lacking variance cannot differentiate between respondents or contribute meaningfully to factor structure and were therefore excluded (DeVellis & Thorpe, 2021; Kline, 2023).

Univariate outliers were identified using Z-scores, with values exceeding $\pm 3SD$ considered extreme. This process identified 218 univariate outliers. Multivariate outliers were detected using Mahalanobis distance, resulting in 98 multivariate outliers. To minimise their influence without losing statistical power, extreme values were adjusted through Winsorisation ($\pm 3 SD$), which retains all observations while reducing distortion from extreme responses (Hatem et al., 2022; Martin et al., 2024; Thériault et al., 2024).

The remaining 24 items were standardised using Z-score transformation (mean = 0, standard deviation = 1) to ensure comparability and reduce scale-related bias (Jebb et

al., 2021; Kyriazos, 2018). Multivariate normality was assessed using Mardia's test, which indicated significant deviations (skewness $b1p = 921.9$, $p \leq 0.001$; kurtosis $b2p = 1774.76$, $p \leq 0.001$), justifying the application of robust estimation methods (Brown, 2015; Mardia, 1970).

For psychometric evaluation, the processed dataset ($n = 731$) was randomly split into two subsets: approximately 40% ($n = 292$) for exploratory factor analysis (EFA) and 60% ($n = 439$) for confirmatory factor analysis (CFA). Randomisation was performed using a fixed seed (123) to ensure reproducibility (Kyriazos, 2018). The EFA sample size exceeded the recommended criterion of 5–10 respondents per item (White, 2022), and the CFA sample exceeded the minimum of 200–300 participants required for stable model estimation (Kline, 2023; Smith, 2021). Background characteristics of participants were summarised using descriptive statistics. All analyses were conducted using R software (version 4.3.1) and the *lavaan* package in RStudio (Lin, 2021).

Exploratory Factor Analysis (EFA)

Exploratory factor analysis was conducted to examine the underlying structure of the 24-item questionnaire and to explore whether the data supported a two-factor structure consistent with the theorised constructs of Perception and Acceptance (Byrne, 2013). Sampling adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) measure, with values ≥ 0.80 considered meritorious for factor analysis (Kaiser, 1974). Bartlett's test of sphericity was also performed to assess whether the correlation matrix was suitable for factor analysis, with a significant result at $p < 0.05$ indicating that the inter-item correlations were sufficient for factor extraction (Shrestha, 2021; Widaman & Helm, 2023).

A two-factor solution was specified *a priori* based on theoretical expectations and further supported by parallel analysis, which indicated that only the first two eigenvalues exceeded the 95th percentile random criterion. Principal Axis Factoring was used as the extraction method, and Direct Oblimin rotation was applied to allow for correlation between the two factors (Akhtar-Danesh, 2023; Widaman & Helm, 2023). Items were retained if their primary factor loading exceeded 0.40 and did not exhibit substantial cross-loading (≥ 0.30) on other factors, consistent with established guidelines for factor interpretability (Stevens, 2002; Tabachnick, 2019).

Confirmatory factor analysis (CFA) and model validation

Confirmatory factor analysis (CFA) was conducted to validate the two-construct model identified through EFA, assessing the relationships between observed items and their corresponding latent constructs (Perception and Acceptance) (Brown, 2015; Widaman & Helm, 2023). Due to the ordinal nature of the data and significant deviations from multivariate normality, the weighted least squares mean and variance adjusted (WLSMV) estimator was used (Jing, 2024; Li, 2021). A scaling correction factor of 1.104 was applied to the chi-square statistic to ensure accurate interpretation of robust model fit indices (Brown, 2015; Li, 2016).

Model fit was evaluated using multiple standard indices. The Root Mean Square Error of Approximation (RMSEA) ≤ 0.06 indicated good fit, with values between 0.06 and 0.08 considered acceptable (Groskurth et al., 2024; Mw, 1993). Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values ≥ 0.95 reflected excellent fit, while values between 0.90 and 0.95 were deemed acceptable. A Standardised Root Mean Square

Residual (SRMR) ≤ 0.08 indicated adequate fit (Goretzko et al., 2024; McNeish & Wolf, 2023). The normed Chi-square (χ^2/df) was also reported, with values < 3 indicating acceptable model parsimony (Alavi et al., 2020b).

Beyond overall model fit, construct validity was evaluated to determine how well the observed items represented the intended theoretical constructs (Boateng et al., 2018; Henseler et al., 2015). Convergent validity, the extent to which items within a factor are correlated, was assessed using Average Variance Extracted (AVE), with values > 0.50 indicating adequate convergence (Cheung et al., 2024). Discriminant validity was assessed using the Fornell–Larcker criterion, whereby the square root of the AVE for each construct exceeded the inter-construct correlation (Fornell & Larcker, 1981). Internal consistency and construct reliability were evaluated using Cronbach’s alpha and composite reliability (CR), with values ≥ 0.70 considered acceptable (Hair Jr et al., 2020; Sujati & Akhyar, 2020).

To further assess convergent validity, factor loadings were examined to evaluate the strength of the relationships between observed items and their respective latent constructs. Standardised factor loadings were examined, with items loading ≥ 0.40 retained. Loadings ≥ 0.50 were considered acceptable, while values ≥ 0.70 indicated strong associations (Hair Jr et al., 2020; Stevens, 2002).

Model refinement followed standard CFA procedures to improve overall fit. Correlation between the two constructs was permitted based on theoretical expectations. Items with standardised factor loadings below 0.40 or exhibiting substantial cross-loadings were considered for removal, provided that their exclusion did not compromise theoretical or content validity.

Results

Background characteristics

A total of 731 participants were included in the study (**Table 1**). The mean age was 40.8 years (SD = 17.4), and 58.8% were female. Participants' relationships to the household head were as follows: 27.9% were household heads, 38.6% were spouses, 9.4% were parents of household heads, 13.8% were sons or daughters, and 10.3% were siblings or mothers-in-law.

In terms of household cooking roles, 40.0% reported never cooking, 38.4% were the primary cooks, and 21.6% cooked occasionally. Educational attainment was low, with 74.8% having no formal education, 13.0% having completed basic education, and 12.2% having completed senior high school or higher. Most participants identified as Dagomba (98.9%) and were Muslim (98.4%). Regarding occupation, 46.8% were engaged in agriculture or farming, 16.7% were homemakers, 28.9% operated small businesses, and 7.7% were employed in government or private sector jobs.



Table 1. Background characteristics of the study participants for the Focus Group Discussions in the Northern Region of Ghana¹ (total n = 731)

Variables/characteristics	Frequencies (%)
Age, years (<i>Mean ± S.D</i>)	40.8 ± 17.4
Sex	
Female	437 (58.8)
Relationship with household head (HH)	
Household head	204 (27.9)
Wife of HH	282 (38.6)
Father/mother of HH	69 (9.4)
Sons/daughters of HH	101 (13.8)
Siblings/mother in-law of HH	75 (10.3)
Position in household cooking	
Never cook	292 (40.0)
Primary cook	281 (38.4)
Occasional/rarely cook	158 (21.6)
Educational level completed	
No Formal Education	547 (74.8)
Basic Education	95 (13.0)
Senior High School or Higher	89 (12.2)
Ethnicity	
Dagomba	723(98.9)
Gonja/Mosi	8 (1.1)
Religion	
Islam	719 (98.4)
Christianity	12 (1.6)
Occupation	
Agriculture/Farming	342 (46.8)
Homemaker	122 (16.7)
Small Business Owner	211 (28.9)
Government/ Private Employee	56 (7.7)

Abbreviations: HH, Household Head.

¹Values are reported as means and standard deviation for continuous variable and count and percentages for categorical variables



EFA Results

The KMO measure of sampling adequacy was 0.85, indicating that the sample was suitable for factor analysis. Bartlett's test of sphericity was significant, $\chi^2(276) = 2156.05$, $p < 0.001$, confirming that the inter-item correlations were sufficient for factor extraction.

Exploratory factor analysis (EFA) revealed a two-factor structure, comprising Factor 1 (Perception) and Factor 2 (Acceptance), as shown in Table 2.

For the Perception factor, loadings ranged from 0.47 (Q6) to 0.76 (Q27). Eight items were retained: Q1, Q3, Q4, Q6, Q23, Q24, Q26, and Q27. For the Acceptance factor, loadings ranged from 0.43 (Q10) to 0.67 (Q20). Eleven items were retained: Q2, Q5, Q7, Q10, Q16, Q17, Q18, Q20, Q25, Q28, and Q29. No items cross-loaded at ≥ 0.30 on both factors.

Together, the two factors explained 56% of the total variance, with Acceptance accounting for 31% and Perception for 25%, which is within the acceptable range for behavioural constructs. Internal consistency was acceptable, with Cronbach's alpha values of 0.71 for Perception and 0.72 for Acceptance.

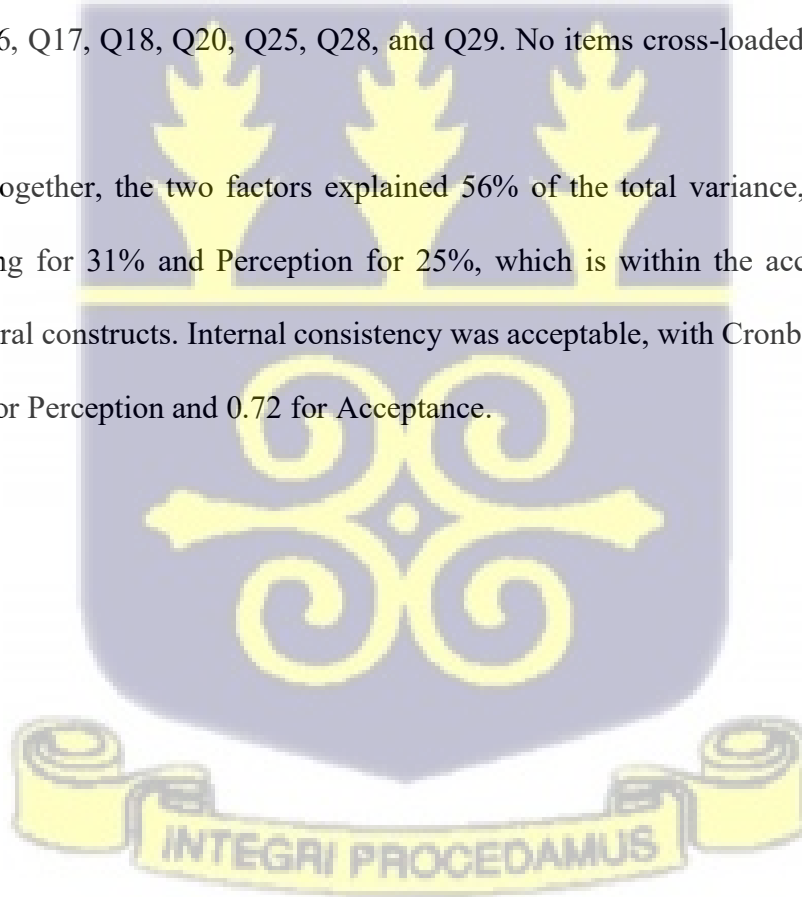
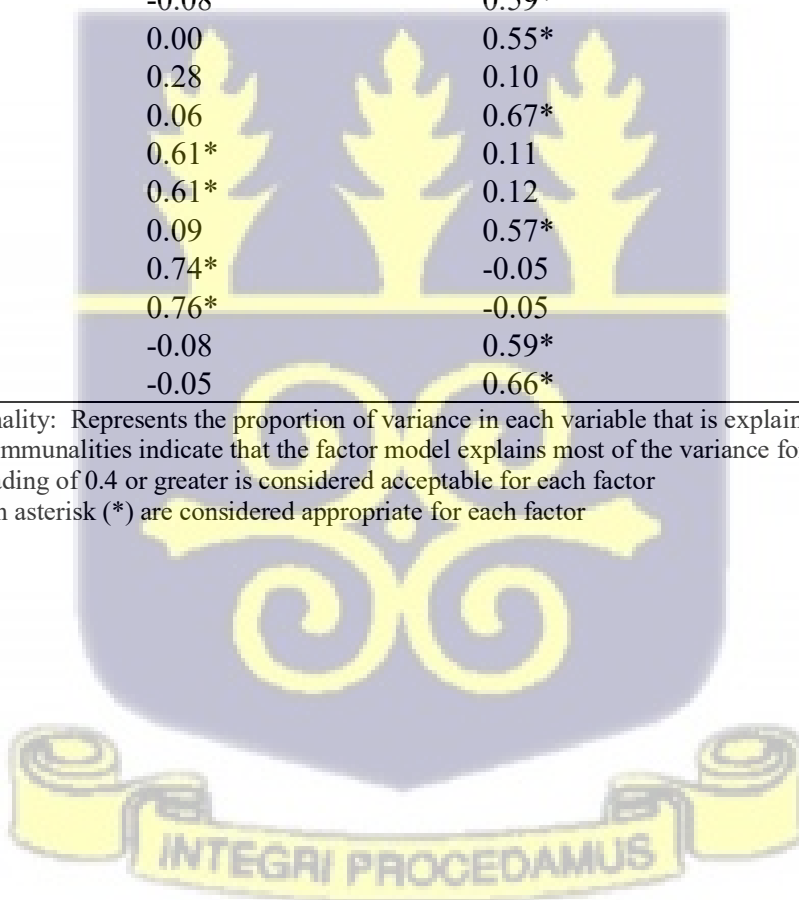


Table 2. Factor loadings from the exploratory factor analysis (EFA) using principal axis factoring extraction with Oblimin rotation¹ (total n = 292)

Question	Factor 1 (Perception)	Factor 2 (Acceptance)	Communality
Q1	0.70*	-0.04	0.498
Q2	-0.02	0.57*	0.331
Q3	0.72*	-0.03	0.527
Q4	0.74*	0.02	0.546
Q5	-0.04	0.50*	0.255
Q6	0.47*	-0.14	0.251
Q7	0.03	0.46*	0.213
Q10	0.03	0.43*	0.184
Q11	0.33	0.35	0.201
Q12	0.18	0.35	0.136
Q13	-0.09	0.16	0.037
Q14	0.01	0.02	0.000
Q16	-0.12	0.44*	0.224
Q17	-0.08	0.59*	0.371
Q18	0.00	0.55*	0.305
Q19	0.28	0.10	0.081
Q20	0.06	0.67*	0.445
Q23	0.61*	0.11	0.367
Q24	0.61*	0.12	0.363
Q25	0.09	0.57*	0.317
Q26	0.74*	-0.05	0.551
Q27	0.76*	-0.05	0.584
Q28	-0.08	0.59*	0.365
Q29	-0.05	0.66*	0.446

¹Communality: Represents the proportion of variance in each variable that is explained by the extracted factors. Higher communalities indicate that the factor model explains most of the variance for the variable. Factor loading of 0.4 or greater is considered acceptable for each factor. Items with asterisk (*) are considered appropriate for each factor.



Confirmatory Factor Analysis- Results

Final standardised factor loadings

Standardised factor loadings from the CFA are presented in **Table 3**. All retained items exceeded the pre-established threshold of ≥ 0.40 , supporting their inclusion in their respective latent constructs. Although 11 items initially loaded on the Acceptance construct in the EFA, one item (Q7) showed a low standardised factor loading (0.35) in the CFA and was excluded. This resulted in a final 10-item Acceptance construct, consistent with theoretical expectations.

For the Perception construct, standardised loadings ranged from 0.464 (Q24) to 0.770 (Q1). Additional loadings included Q3 (0.756), Q4 (0.719), Q6 (0.483), Q23 (0.520), Q26 (0.743), and Q27 (0.756).

For the Acceptance construct, standardised loadings ranged from 0.476 (Q5) to 0.692 (Q29). The remaining items had loadings as follows: Q2 (0.525), Q10 (0.486), Q16 (0.538), Q17 (0.606), Q18 (0.578), Q20 (0.607), Q25 (0.553), and Q28 (0.574).

Table 3. Standardised factor loadings from the confirmatory factor analysis (CFA) model for validation¹ (total n = 439)

Perception construct		Acceptance construct	
Items	Standardised factor loadings	Items	Standardised factor loadings
Q1	0.770	Q2	0.525
Q3	0.756	Q5	0.476
Q4	0.719	Q10	0.486
Q6	0.483	Q16	0.538
Q23	0.520	Q17	0.606
Q24	0.464	Q18	0.578
Q26	0.743	Q20	0.607
Q27	0.756	Q25	0.553
		Q28	0.574
		Q29	0.692

¹Factor loading of 0.4 is deemed acceptable

Model indices and validation results

Table 4 presents the model fit indices and construct validation results from the CFA. The CFA indicated acceptable to excellent model fit based on multiple criteria: $\chi^2(134) = 255.94$, $p < 0.001$; $\chi^2/df = 1.91$; RMSEA = 0.043 (90% CI: 0.035–0.052); CFI = 0.981; TLI = 0.977; and SRMR = 0.061. Although the chi-square test was statistically significant ($p < 0.001$), this result is expected with large samples and does not, by itself, indicate poor model fit. Other fit indices (CFI, TLI, RMSEA, SRMR) were within acceptable ranges, confirming that the overall model fit was adequate.

Composite reliability (CR) was 0.86 for the Perception construct and 0.82 for Acceptance, exceeding the recommended minimum of 0.70, thereby indicating strong internal consistency. The average variance extracted (AVE) was 0.52 for Perception and 0.46 for Acceptance. The Average Variance Extracted (AVE) for the Acceptance construct was 0.46, indicating marginal convergent validity but adequate composite reliability.

One item (Q7) from the Acceptance construct was removed due to a low standardised factor loading (0.35), which persisted despite allowing for correlated error terms. This removal improved model fit but did not compromise content validity, as the remaining items continued to represent all conceptual domains originally defined for the Acceptance construct. Its exclusion was justified by its weak association with the latent construct (Cheung et al., 2024; Rönkkö & Cho, 2022).

Four items showed borderline factor loadings: Q5 (0.48), Q6 (0.48), Q10 (0.49), and Q24 (0.46). These items were retained because of their theoretical importance in capturing perceived behavioural control, normative approval, and experiential feedback, core constructs within the underlying behavioural frameworks (Theory of Planned Behaviour and Health Belief Model). Retaining them ensured that the multidimensional

nature of the Acceptance construct was preserved without compromising overall model fit or conceptual validity.

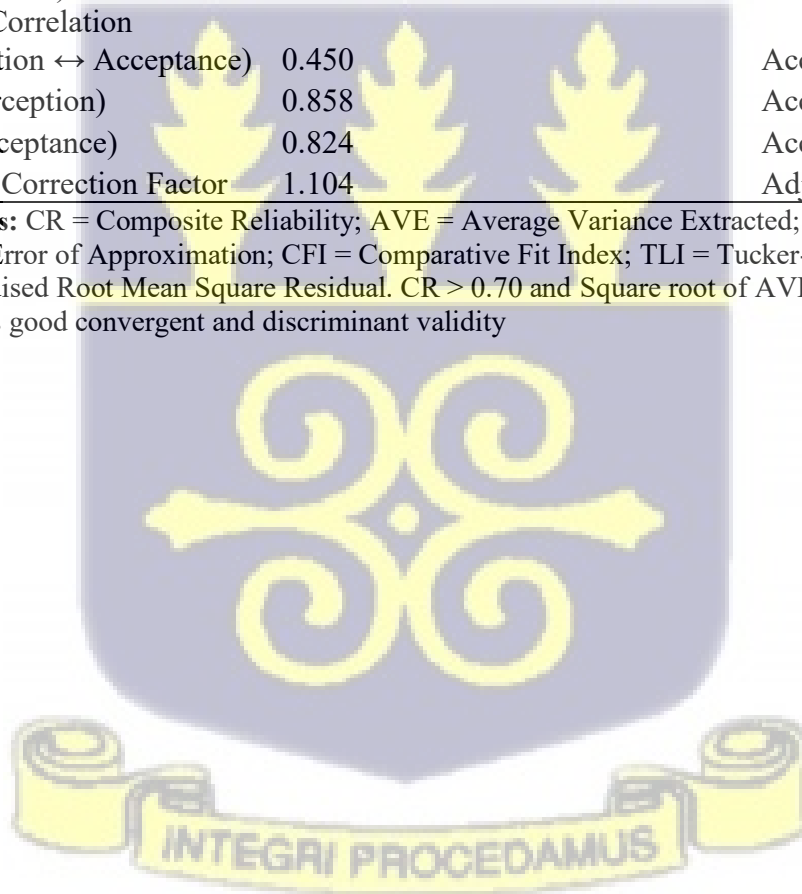
The correlation between Perception and Acceptance was $r = 0.45$, indicating a moderate association. This suggests related but distinct constructs, consistent with the conceptual separation of beliefs and behavioural intentions proposed by the Theory of Planned Behaviour. However, discriminant validity was supported. Thus, the square root of the AVE was 0.72 for Perception and 0.68 for Acceptance, both exceeding the inter-construct correlation of 0.45, consistent with the Fornell–Larcker criterion. These results collectively support a two-factor model with acceptable reliability and validity, consistent with the theoretical expectations.



Table 4. Summary of model fit indices, factor reliability, and discriminant validity for the confirmatory factor analysis (CFA) model

Measure	Value	Interpretation
RMSEA	0.043 (90% CI: 0.035–0.052)	Excellent fit (< 0.05)
CFI	0.981	Excellent fit (≥ 0.95)
TLI	0.977	Excellent fit (≥ 0.95)
SRMR	0.061	Good fit (≤ 0.08)
Chi-Square/df	1.910	Acceptable fit (< 3)
AVE (Perception)	0.520	Acceptable (≥ 0.50)
AVE (Acceptance)	0.460	Below threshold, but marginal
Square root of AVE (Perception)	0.721	Exceeds correlation with other construct (supports discriminant validity)
Square root of AVE (Acceptance)	0.678	Exceeds correlation with other construct (supports discriminant validity)
Latent Correlation (Perception $\leftrightarrow$ Acceptance)	0.450	Acceptable ($< \sqrt{\text{AVE}}$)
CR (Perception)	0.858	Acceptable (≥ 0.70)
CR (Acceptance)	0.824	Acceptable (≥ 0.70)
Scaling Correction Factor	1.104	Adjustment for non-normality

Footnotes: CR = Composite Reliability; AVE = Average Variance Extracted; RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SRMR = Standardised Root Mean Square Residual. CR > 0.70 and Square root of AVE $>$ inter-construct correlation indicates good convergent and discriminant validity



Discussion

This study developed and validated an 18-item questionnaire to assess ‘Perceptions’ (8 items) and ‘Acceptance’ (10 items) of micronutrient-fortified bouillon cubes among non-index household members in northern Ghana. Factor analyses confirmed a two-factor structure explaining 56% of the variance, indicating a well-fitting and theoretically coherent model. Internal consistency was acceptable (Cronbach’s alpha: 0.71 for Perception, 0.72 for Acceptance; composite reliability: 0.86 and 0.82, respectively). Convergent validity was confirmed for Perception (AVE = 0.52) and was marginal for Acceptance (AVE = 0.46), while discriminant validity was supported by the Fornell–Larcker criterion.

A key strength was that the questionnaire was theory-driven, drawing on constructs from the Theory of Planned Behaviour and the Health Belief Model (Ajzen, 1991; Rosenstock, 1974). The questionnaire was reviewed by experts, pre-tested, and field-tested within a randomised controlled trial context (Boateng et al., 2018). The use of both exploratory and confirmatory factor analysis on independent samples and the application of robust estimation methods (WLSMV) addressed the ordinal nature of the data and non-normality, enhancing the validity of the findings (Brown, 2015; Li, 2016).

While internal consistency and structural validity were supported, the AVE for the Acceptance construct (0.46) was slightly below the recommended threshold (0.50), which may reflect conceptual overlap or measurement limitations (Cheung et al., 2024). However, the high composite reliability (0.82) indicates that the construct maintained acceptable internal consistency despite the marginal AVE (Fornell & Larcker, 1981; Hair Jr et al., 2020). Additionally, the study’s cross-sectional design and single-region setting may limit

generalisability to other populations with different cultural or dietary practices (Alavi et al., 2020a). Criterion validity was not assessed, and future research should examine how perceptions and acceptance relate to actual usage or nutritional outcomes (Boateng et al., 2018; DeVellis & Thorpe, 2021).

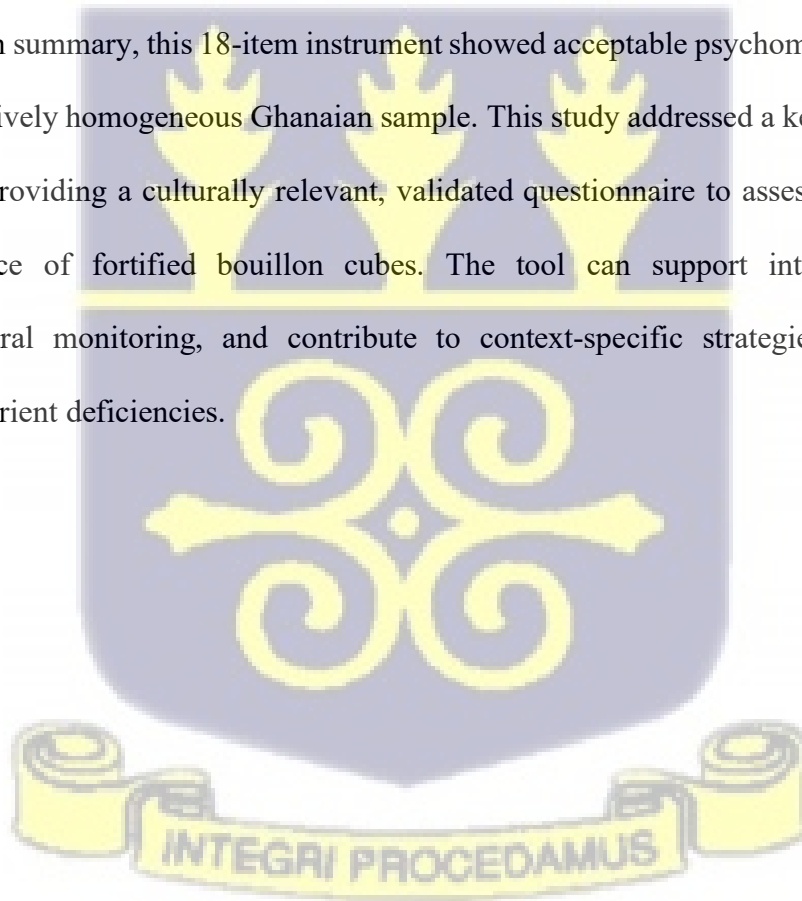
The two-factor structure “Perception and Acceptance” reflects distinct but related behavioural dimensions, consistent with the Theory of Planned Behaviour, which distinguishes between beliefs and behavioural intentions (Ajzen, 1991). The moderate correlation ($r = 0.45$) supports this differentiation and aligns with findings from similar behavioural instrument validations (Boateng et al., 2018; Dunn et al., 2014). All factor loadings exceeded 0.40 and composite reliability was high (0.82), indicating acceptable internal consistency. Cronbach’s alpha values (0.71 and 0.72) were at the lower bound of the acceptable range but are typical for behavioural constructs of this nature. The total variance explained (56%) is considered adequate for instruments measuring psychosocial constructs, acknowledging that the remaining unexplained variance may reflect unmeasured contextual or individual influences. The study’s reliability values are within the acceptable range for new psychosocial scales, but they remain modest and should be improved through item refinement and retesting in diverse samples. The study’s findings are broadly comparable with other validated food-related instruments. For the East African Food Literacy Scale achieved Cronbach’s alpha of 0.71–0.78 with confirmed construct validity across Uganda and Kenya (Yiga et al., 2024). More recently, the Ultra-Processed Food Acceptance Scale in Spain and Portugal identified multiple acceptance dimensions (Calvo-Porràl et al., 2024)

The validated questionnaire can be applied in both research and public health programme contexts to assess household acceptance and perception of fortified condiments. These constructs are relevant for informing communication strategies and intervention design (Allen, 2006). In programme settings, the tool can support the planning and adaptation of fortification initiatives. It is relevant for ministries of health, non-governmental organization and other implementing partners. It may be used to identify specific concerns through item-level responses or to generate composite scores for monitoring and evaluation purposes. For example, low scores could flag households needing targeted engagement to address misconceptions about fortification interventions. Programmes may set pragmatic cut-offs (e.g., the lowest quintile) for targeted counselling. However, formal threshold validation is recommended before prespecifying programmatic triggers. The moderate association observed between perception and acceptance indicates that improving perceptions alone may not be sufficient to ensure adoption. Interventions should also address practical barriers, including taste preferences, cost, and cooking practices, to support sustained use (Tumilowicz et al., 2015). Because fortified condiments are used at the household level, the views of all household members should be considered. This includes not only the primary beneficiaries but also others involved in food preparation and decision-making. Although the tool was developed for fortified bouillon cubes, the approach may be adapted for other fortified foods that are consumed at the household level. This flexibility makes it relevant for a range of food fortification programmes beyond bouillon.

Future research should assess this tool's generalisability in different regions and cultural settings. Longitudinal studies can help evaluate changes over time in response to

behaviour change interventions or market factors(Rodas-Moya et al., 2023; Tsang et al., 2017). Further validation is recommended, including predictive and criterion-related validity. These analyses could explore associations with both consumption behaviours and health outcomes (De Vet et al., 2011; Kline, 2023). Measurement invariance across subgroups (e.g., gender, age, or district) was not tested in this initial validation. This limits the ability to confirm whether the constructs operate equivalently across groups. Future studies should assess factorial invariance to ensure the instrument's comparability across diverse populations. Item refinement, particularly within the Acceptance construct, may also enhance measurement precision.

In summary, this 18-item instrument showed acceptable psychometric performance in a relatively homogeneous Ghanaian sample. This study addressed a key methodological gap by providing a culturally relevant, validated questionnaire to assess perceptions and acceptance of fortified bouillon cubes. The tool can support intervention design, behavioural monitoring, and contribute to context-specific strategies for addressing micronutrient deficiencies.



REFERENCE

- Abizari, A.-R., Dold, S., Kupka, R., & Zimmermann, M. B. (2017). More than two-thirds of dietary iodine in children in northern Ghana is obtained from bouillon cubes containing iodized salt. *Public Health Nutrition*, 20(6), 1107-1113.
- Adams, K. P., Vosti, S. A., Somé, J. W., Tarini, A., Becher, E., Koudougou, K., & Engle-Stone, R. (2024). Micronutrient-fortified bouillon as a strategy to improve the micronutrient adequacy of diets in Burkina Faso. *Annals of the new York Academy of Sciences*.
- Adu-Afarwuah, S., Lartey, A., Brown, K. H., Zlotkin, S., Briend, A., & Dewey, K. G. (2008). Home fortification of complementary foods with micronutrient supplements is well accepted and has positive effects on infant iron status in Ghana. *The American journal of clinical nutrition*, 87(4), 929-938.
- Ajzen, I. (1991). The theory of planned behaviour. *Organizational behaviour and human decision processes*, 50(2), 179-211.
- Akhtar-Danesh, N. (2023). Impact of factor rotation on Q-methodology analysis. *PloS one*, 18(9), e0290728.
- Alavi, M., Visentin, D. C., Thapa, D. K., Hunt, G. E., Watson, R., & Cleary, M. (2020a). Chi-square for model fit in confirmatory factor analysis. *Journal of advanced nursing*, 76(9), 2209-2211.
- Alavi, M., Visentin, D. C., Thapa, D. K., Hunt, G. E., Watson, R., & Cleary, M. (2020b). Exploratory factor analysis and principal component analysis in clinical studies: Which one should you use. *Journal of advanced nursing*, 76(8), 1886-1889.
- Allen, L. (2006). *Guidelines on food fortification with Micronutrients*. Citeseer.
- Archer, N. S., Cochet-Broch, M., Mihnea, M., Garrido-Bañuelos, G., Lopez-Sanchez, P., Lundin, L., & Frank, D. (2022). Sodium Reduction in Bouillon: Targeting a Food Staple to Reduce Hypertension in Sub-Saharan Africa. *Front Nutr*, 9, 746018. <https://doi.org/10.3389/fnut.2022.746018>
- Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, 25(24), 3186-3191.
- Beressa, G., Whiting, S. J., & Belachew, T. (2024). Effect of nutrition education integrating the health belief model and theory of planned behaviour on dietary diversity of pregnant women in Southeast Ethiopia: a cluster randomised controlled trial. *Nutrition Journal*, 23(1), 3. <https://doi.org/10.1186/s12937-023-00907-z>
- Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quinonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioural research: a primer. *Frontiers in Public Health*, 6, 149.
- Brown, T. A. (2015). *Confirmatory factor analysis for applied research*. Guilford publications.
- Byrne, B. M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. routledge.
- Caso, D., Canova, L., Capasso, M., & Bianchi, M. (2024). Integrating the theory of planned behaviour and the self-determination theory to promote Mediterranean diet adherence: A randomised controlled trial. *Applied Psychology: Health and Well-Being*, 16(1), 80-101.

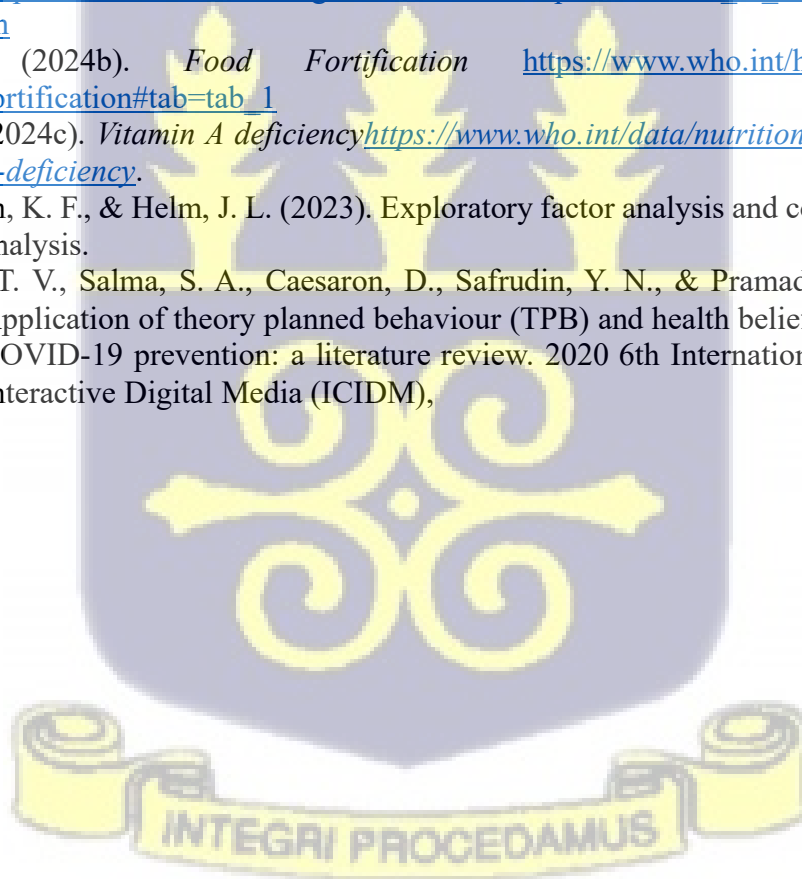
- Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2024). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. *Asia Pacific Journal of Management*, 41(2), 745-783.
- de Almeida Costa, A. I., Monteiro, M. J. P., & Lamy, E. (2024). *Sensory Evaluation and Consumer Acceptance of New Food Products: Principles and Applications* (Vol. 43). Royal Society of Chemistry.
- De Vet, H. C., Terwee, C. B., Mokkink, L. B., & Knol, D. L. (2011). *Measurement in medicine: a practical guide*. Cambridge university press.
- DeVellis, R. F., & Thorpe, C. T. (2021). *Scale development: Theory and applications*. Sage publications.
- Duggal, M., Sesikeran, B., Arlappa, N., Nair, S., Shekhar, V., & Sabharwal, V. (2022). Large-scale staple food fortification as a complementary strategy to address vitamin and mineral vulnerabilities in India: A critical review. *Indian J Public Health*, 66(3), 313-320. https://doi.org/10.4103/ijph.ijph_708_22
- Dunn, T. J., Baguley, T., & Brunsden, V. (2014). From alpha to omega: A practical solution to the pervasive problem of internal consistency estimation. *British journal of psychology*, 105(3), 399-412.
- Eilander, A., Verbakel, M. R., & Dötsch-Klerk, M. (2023). The Potential of Condiments, Seasonings, and Bouillon Cubes to Deliver Essential Micronutrients in Asia: Scenario Analyses of Iodine and Iron Fortification. *Nutrients*, 15(3), 616.
- Engle-Stone, R., Adams, K., Kumordzie, S., Luo, H., Wessells, K. R., Adu-Afarwuah, S., Ndjebayi, A., Teta, I., Régis, Y.-L., & Haskell, M. (2021). Analyses using national survey data from Cameroon, Haiti, and Ghana indicate the potential for bouillon fortification to help fill dietary gaps for 5 nutrients. *Current Developments in Nutrition*, 5, 640.
- Engle-Stone, R., Wessells, K. R., Haskell, M. J., Kumordzie, S. M., Arnold, C. D., Davis, J. N., Becher, E. R., Fuseini, A. D., Nyaaba, K. W., & Tan, X. (2024). Effect of multiple micronutrient-fortified bouillon on micronutrient status among women and children in the Northern Region of Ghana: Protocol for the Condiment Micronutrient Innovation Trial (CoMIT), a community-based randomised controlled trial. *PloS one*, 19(5), e0302968.
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 18(1), 39-50.
- GAIN. (2023). *Regulatory monitoring of national food fortification programs: A policy guidance document*. <https://www.gainhealth.org/sites/default/files/publications/documents/regulatory-monitoring-policy-guidance-doc-2018.pdf>
- Geicu-Cristea, M., Popa, E. E., & Tenagashaw, M. W. (2024). Consumers' Perceptions of Fortified Foods. In D. Bogueva (Ed.), *Consumer Perceptions and Food* (pp. 589-604). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-7870-6_28
- Geny, A., Petitjean, M., Vanwymelbeke-Delannoy, V., & Sulmont-Rossé, C. (2023). IMPACT OF FOOD FORTIFICATION ON NUTRITIONAL OUTCOMES AND ACCEPTABILITY IN OLDER PEOPLE: SYSTEMATIC LITERATURE REVIEW. *Frontiers in nutrition*, 10, 1232502.

- Glanz, K., Rimer, B. K., & Viswanath, K. (2015). *Health behaviour: Theory, research, and practice*. John Wiley & Sons.
- Goretzko, D., Siemund, K., & Sterner, P. (2024). Evaluating model fit of measurement models in confirmatory factor analysis. *Educational and Psychological Measurement*, 84(1), 123-144.
- Groskurth, K., Bluemke, M., & Lechner, C. M. (2024). Why we need to abandon fixed cutoffs for goodness-of-fit indices: An extensive simulation and possible solutions. *Behaviour research methods*, 56(4), 3891-3914. <https://doi.org/10.3758/s13428-023-02193-3>
- Hair Jr, J. F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, 109, 101-110.
- Hatem, G., Zeidan, J., Goossens, M., & Moreira, C. (2022). Normality testing methods and the importance of skewness and kurtosis in statistical analysis. *BAU Journal-Science and Technology*, 3(2), 7.
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science*, 43, 115-135.
- Jebb, A. T., Ng, V., & Tay, L. (2021). A review of key Likert scale development advances: 1995–2019. *Frontiers in psychology*, 12, 637547.
- Jing, J. (2024). Confirmatory factor analysis with ordinal variables: A comparison of different estimation methods. In.
- Kaiser, H. F. (1974). An index of factorial simplicity. *psychometrika*, 39(1), 31-36.
- Keats, E. C., Neufeld, L. M., Garrett, G. S., Mbuya, M. N., & Bhutta, Z. A. (2019). Improved micronutrient status and health outcomes in low-and middle-income countries following large-scale fortification: evidence from a systematic review and meta-analysis. *The American journal of clinical nutrition*, 109(6), 1696-1708.
- Kline, R. B. (2023). *Principles and practice of structural equation modeling*. Guilford publications.
- Kroke, A. M., & Ruthig, J. C. (2024). Conspiracy beliefs predicting health behaviours: an integration of the theory of planned behaviour and health belief model. *Current Psychology*, 43(9), 7959-7973. <https://doi.org/10.1007/s12144-023-04953-y>
- Kumordzie, S., Davis, J., Adams, K., Tan, X., Adu-Afarwuah, S., Wessells, K. R., Arnold, C., Becher, E., Haskell, M., & Vosti, S. (2021). Understanding Patterns and Drivers of Bouillon Use in Northern Ghana to Inform Fortification Planning. *Current Developments in Nutrition*, 5, 5140655.
- Kyriazos, T. A. (2018). Applied psychometrics: sample size and sample power considerations in factor analysis (EFA, CFA) and SEM in general. *Psychology*, 9(08), 2207.
- Li, C.-H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. *Behaviour research methods*, 48, 936-949.
- Li, C.-H. (2021). Statistical estimation of structural equation models with a mixture of continuous and categorical observed variables. *Behaviour research methods*, 53(5), 2191-2213.

- Lin, J. (2021). Introduction to Structural Equation Modeling (SEM) in R with lavaan. *Los Angeles, California*.
- Mao, C., Shen, Z., Long, D., Liu, M., Xu, X., Gao, X., Lin, Y., & Wang, X. (2024). Epidemiological study of pediatric nutritional deficiencies: an analysis from the global burden of disease study 2019. *Nutrition Journal*, 23(1), 44.
- Mardia, K. V. (1970). Measures of multivariate skewness and kurtosis with applications. *Biometrika*, 57(3), 519-530.
- Martin, R. D., Guerard, J. B., & Xia, D. Z. (2024). Resurrecting Earnings-to-Price with Robust Control for Outliers. *Journal of Portfolio Management*, 50(9).
- McNeish, D., & Wolf, M. G. (2023). Dynamic fit index cutoffs for confirmatory factor analysis models. *Psychological methods*, 28(1), 61.
- Moretti, D., Hurrell, R. F., & Cercamondi, C. I. (2018). Bouillon cubes. In *Food fortification in a globalized world* (pp. 159-165). Elsevier.
- Mw, B. (1993). Alternative ways of assessing model fit. *Testing structural equation models*.
- Nyumuah, R. O., Hoang, T. C., Amoah, E. F., Agble, R., Meyer, M., Wirth, J. P., Locatelli-Rossi, L., & Panagides, D. (2012). Implementing large-scale food fortification in Ghana: lessons learned. *Food Nutr Bull*, 33(4 Suppl), S293-300. <https://doi.org/10.1177/15648265120334s305>
- Olson, R., Gavin-Smith, B., Ferraboschi, C., & Kraemer, K. (2021). Food Fortification: The Advantages, Disadvantages and Lessons from Sight and Life Programs. *Nutrients*, 13(4). <https://doi.org/10.3390/nu13041118>
- Osendarp, S. J. M., Martinez, H., Garrett, G. S., Neufeld, L. M., De-Regil, L. M., Vossenaar, M., & Darnton-Hill, I. (2018). Large-Scale Food Fortification and Biofortification in Low- and Middle-Income Countries: A Review of Programs, Trends, Challenges, and Evidence Gaps. *Food Nutr Bull*, 39(2), 315-331. <https://doi.org/10.1177/0379572118774229>
- Petry, N., Wirth, J. P., Adu-Afarwuah, S., Wegmuller, R., Woodruff, B. A., Tanumihardjo, S. A., Bentil, H., Donkor, W. E. S., Williams, T. N., Shahab-Ferdows, S., Selenje, L., Mahama, A., Steiner-Asiedu, M., & Rohner, F. (2021). Risk factors for anaemia among Ghanaian women and children vary by population group and climate zone. *Matern Child Nutr*, 17(2), e13076. <https://doi.org/10.1111/mcn.13076>
- Rai, A., Maharjan, M. R., Harris Fry, H. A., Chhetri, P. K., Wasti, P. C., & Saville, N. M. (2019). Consumption of rice, acceptability and sensory qualities of fortified rice amongst consumers of social safety net rice in Nepal. *PloS one*, 14(10), e0222903.
- Rodas-Moya, S., Giudici, F. M., Owolabi, A., Samuel, F., Kodish, S. R., Lachat, C., Abreu, T. C., van het Hof, K. H., Osendarp, S. J., & Brouwer, I. D. (2023). A generic theory of change-based framework with core indicators for monitoring the effectiveness of large-scale food fortification programs in low-and middle-income countries. *Frontiers in nutrition*, 10, 1163273.
- Rohner, F., Wirth, J. P., Zeng, W., Petry, N., Donkor, W., Neufeld, L. M., Mkambula, P., Groll, S., Mbuya, M. N., & Friesen, V. M. (2023). Global coverage of mandatory large-scale food fortification programs: a systematic review and meta-analysis. *Advances in Nutrition*.
- Rönkkö, M., & Cho, E. (2022). An updated guideline for assessing discriminant validity. *Organizational Research Methods*, 25(1), 6-14.

- Rosenstock, I. M. (1974). Historical origins of the health belief model. *Health education monographs*, 2(4), 328-335.
- Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American journal of Applied Mathematics and statistics*, 9(1), 4-11.
- Smith, S. C., & Johnston, W. (2021). Challenges in developing validated tools for assessing consumer perceptions of food products in low-resource settings. *Journal of Nutrition Education and Behaviour*, 53(2), 123-134.
- Srivastava, S. K., Mishra, A., Singh, S., & Jaiswal, D. (2023). Household food waste and theory of planned behaviour: A systematic review and meta-analysis. *Environmental Science and Pollution Research*, 30(43), 97645-97659. <https://doi.org/10.1007/s11356-023-29141-0>
- Stevens, G. A., Paciorek, C. J., Flores-Urrutia, M. C., Borghi, E., Namaste, S., Wirth, J. P., Suchdev, P. S., Ezzati, M., Rohner, F., & Flaxman, S. R. (2022). National, regional, and global estimates of anaemia by severity in women and children for 2000–19: a pooled analysis of population-representative data. *The Lancet Global Health*, 10(5), e627-e639.
- Stevens, J. (2002). *Applied multivariate statistics for the social sciences* (Vol. 4). Lawrence Erlbaum Associates Mahwah, NJ.
- Sujati, H., & Akhyar, M. (2020). Testing the construct validity and reliability of curiosity scale using confirmatory factor analysis. *Journal of Educational and Social Research*, 20(4).
- Tchum, S. K., Arthur, F. K., Adu, B., Sakyi, S. A., Abubakar, L. A., Atibilla, D., Amenga-Etego, S., Oppong, F. B., Dzabeng, F., Amoani, B., Gyan, T., Arhin, E., & Poku-Asante, K. (2021). Impact of iron fortification on anaemia and iron deficiency among pre-school children living in Rural Ghana. *PloS one*, 16(2), e0246362. <https://doi.org/10.1371/journal.pone.0246362>
- Thériault, R., Ben-Shachar, M. S., Patil, I., Lüdecke, D., Wiernik, B. M., & Makowski, D. (2024). Check your outliers! An introduction to identifying statistical outliers in R with easystats. *Behaviour research methods*, 56(4), 4162-4172.
- Tsang, S., Royse, C. F., & Terkawi, A. S. (2017). Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine. *Saudi journal of anaesthesia*, 11(Suppl 1), S80-S89.
- Tumilowicz, A., Neufeld, L. M., & Pelto, G. H. (2015). Using ethnography in implementation research to improve nutrition interventions in populations. *Maternal & child nutrition*, 11, 55-72.
- UNICEF. (2017). Ghana micronutrient survey 2017. *UNICEF: Accra, Ghana*.
- UNICEF. (2024). *Large-scale food fortification for the prevention of micronutrient deficiencies in children, women, and communities*. Retrieved 12 August, 2024 from <https://www.unicef.org/sites/default/files/2024-01/UNICEF%20FF%20Guidance-v8.pdf>
- Verbeke, W. (2005). Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants. *Food Quality and Preference*, 16(1), 45-57.
- Wegmüller, R., Bentil, H., Wirth, J. P., Petry, N., Tanumihardjo, S. A., Allen, L., Williams, T. N., Selenje, L., Mahama, A., Amoah, E., Steiner-Asiedu, M., Adu-Afarwuah, S., & Rohner, F. (2020). Anemia, micronutrient deficiencies, malaria, hemoglobinopathies and malnutrition in young children and non-pregnant women

- in Ghana: Findings from a national survey. *PloS one*, 15(1), e0228258. <https://doi.org/10.1371/journal.pone.0228258>
- Wessells, K. R., Kumordzie, S. M., Becher, E., Davis, J. N., Nyaaba, K. W., Zyba, S. J., Arnold, C. D., Tan, X., Vosti, S. A., & Adams, K. P. (2023). Acceptability of Multiple Micronutrient-Fortified Bouillon Cubes among Females and Their Households in 2 Districts in The Northern Region of Ghana. *Current Developments in Nutrition*, 102056.
- Wessells, K. R., Kumordzie, S. M., Becher, E., Davis, J. N., Nyaaba, K. W., Zyba, S. J., Arnold, C. D., Tan, X., Vosti, S. A., & Adams, K. P. (2024). Acceptability of multiple micronutrient-fortified bouillon cubes among women and their households in 2 districts in the Northern Region of Ghana. *Current Developments in Nutrition*, 8(1), 102056.
- White, M. (2022). Sample size in quantitative instrument validation studies: A systematic review of articles published in Scopus, 2021. *Heliyon*, 8(12), e12223. <https://doi.org/10.1016/j.heliyon.2022.e12223>
- WHO. (2024a). *Anaemia in women and children: WHO Global Anaemia estimates, 2021 Edition*. https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_childr_en
- WHO. (2024b). *Food Fortification* https://www.who.int/health-topics/food-fortification#tab=tab_1
- WHO. (2024c). *Vitamin A deficiency* <https://www.who.int/data/nutrition/nlis/info/vitamin-a-deficiency>.
- Widaman, K. F., & Helm, J. L. (2023). Exploratory factor analysis and confirmatory factor analysis.
- Yastica, T. V., Salma, S. A., Caesaron, D., Safrudin, Y. N., & Pramadya, A. R. (2020). Application of theory planned behaviour (TPB) and health belief model (HBM) in COVID-19 prevention: a literature review. 2020 6th International Conference on Interactive Digital Media (ICIDM),



Appendices

Supplemental material 1

The questionnaires that were used for the study

Field worker will say:

I would like to know what you think and feel (or believe) about the CoMIT Project bouillon cubes (i.e. the bouillon your household is receiving from the CoMIT Project). I am going to read some questions or statements to you, and I would like you to tell me how you agree with those questions or statements. Most questions or statements have numbers 1 to 5, with 1 = Completely disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Completely agree.

#	Question	Level of agreement*					
		1	2	3	4	5	99
Q1	What you used to think, feel, and do about bouillon cube use in household cooking has not changed since your household started receiving bouillon cubes from the study (CoMIT Project). <i>Enter the number corresponding to the participant's level of agreement.</i>						
Q2	That it is okay to use the study bouillon cubes in cooking food meant for everyone in your household. <i>Enter the number corresponding to the participant's level of agreement.</i>						
Q3	That the smell from the study bouillon cubes is not different from the other bouillon your household has used before. <i>Enter the number corresponding to the participant's level of agreement.</i>						
Q4	That the taste of the study bouillon cubes is not different from the other bouillon your household has used before. <i>Enter the number corresponding to the participant's level of agreement.</i>						
Q5	That the study bouillon cubes can be used in your household every day during the week. <i>Enter the number corresponding to the participant's level of agreement.</i>						

Q6	That the <i>study bouillon cubes</i> should be used in your household in some, but not all, of the days of the week. <i>Enter the number corresponding to the participant's level of agreement.</i>						
Q7	That the <i>study bouillon cubes</i> can be used in your household any number of times in a day. <i>Enter the number corresponding to the participant's level of agreement.</i>						
Q8	That the <i>study bouillon cubes</i> can be used in any food being prepared in your household, if the person preparing the food chooses to do so. <i>Enter the number corresponding to the participant's level of agreement.</i>						
<i>Read question 9 and enter the corresponding number of the participant's response (1 = good, 2 = bad, 3 = neither good nor bad).</i>							
Q9	Do you think that the study bouillon cubes are (1) good or (2) bad or (3) neither good nor bad or (99) not applicable?						
<i>Say questions 10, 11, and 12 in reference to the 5 levels of agreements described above. Enter the number corresponding to the participant's level of agreement.</i>							
#Question		1	2	3	4	5	
Q10	How do you agree with those who think that the <i>study bouillon cubes</i> are good?						
Q11	How do you agree with those who think that the <i>study bouillon cubes</i> are neither good nor bad?						
Q12	How do you agree with those who think that the <i>study bouillon cubes</i> are bad?						
<i>Read question 13 and enter the number (1 or 2 or 3) corresponding to the participant's opinion.</i>							
Q13	Do you think your household members (1) do more cooking since you started getting the study bouillon cubes than before, (2) cooking has not changed, or (3) you don't know?						
<i>Read question 14 and stick to the responses provided in the question. Enter the number corresponding to the participant's answer that he or she will select.</i>							
Q14	Do you think your household uses the study bouillon (1) every time you/they cook, or (2) nearly every time you/they cook, or (3) some of the time you/they cook, (4) once in a while, or (5) you don't know?						
<i>Read question 15 and enter the corresponding number of the participant's response (1 = like, 2 = not like, 3 = don't know).</i>							

Q15	Do you (1) like or (2) not like the way bouillon is used in your household, or (3) you don't know?				
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Acceptance towards study bouillon cubes

In this section, ask participants about their acceptance of study bouillon cubes. Say each question and refer to the level of agreement for the participant to select from. Next, fill in the box with the number that corresponds to the participant's level of agreement. Enter 99 “not applicable” if the participant is not willing to provide an answer. Do not leave any question unanswered.

Field worker will say:

*I would like to know what you say about your household's use of (or willingness to use) the CoMIT Project bouillon cubes (i.e., the bouillon your household is receiving from the CoMIT Project) now and in the future (acceptance). I am going to read you some statements. I would like you to tell me to what extent you agree with these statements. All the statements have numbers 1 to 5 representing your level of agreement, as follows:
Level of agreement: 1 = Completely disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Completely agree.

#	Question	Level of agreement*					
		1	2	3	4	5	99
Q16	You like the smell of the study bouillon cubes.						
Q17	You like the taste of the study bouillon cubes.						
Q18	You are okay or happy that your household receives the study bouillon						
Q19	That the quantity of the study bouillon cubes your households receives is just fine.						
Q20	That you and your household members like or enjoy foods prepared using the study bouillon cubes.						
Q21	That you would like your household to also purchase non-study bouillon from the market.						
Q22	That in the past month, you think your household should have purchased non-study bouillon from market.						
Q23	That you have not observed any problems with using the study bouillon cubes in your household.						

Q24	That your household members have not observed any problems with using the study bouillon cubes.	☐	☐	☐	☐	☐	☐
Q25	That you have good things to say about the study bouillon cubes.	☐	☐	☐	☐	☐	☐
Q26	That you do not want your household to continue using the study bouillon.	☐	☐	☐	☐	☐	☐
Q27	That you do not think your neighbours or friends would like the study bouillon.	☐	☐	☐	☐	☐	☐
Q28	That you want your household to use the study bouillon in future if it is available.	☐	☐	☐	☐	☐	☐
Q29	That you would be interested in buying the study bouillon if it is sold in future.	☐	☐	☐	☐	☐	☐



CHAPTER SIX

SPECIFIC OBJECTIVE 2

Perception and Acceptance of Micronutrient-Fortified Bouillon Among Non-Index Household Members of Women and Children in a Randomised Trial in Northern Ghana

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Abstract

Background: Bouillon cube fortification could serve as a scalable and culturally appropriate strategy to address micronutrient deficiencies in West Africa. Household members' perceptions and acceptance of bouillon cubes are essential to the success of this fortification strategy. This study aimed to examine changes in perception or acceptance of study (intervention)-supplied bouillon cubes over time and explore the drivers and barriers influencing these changes among non-index household members (NIHMs) in an intervention trial.

Methods: This longitudinal mixed-methods study was nested within a doubly masked clinical trial in the Kumbungu and Tolon districts in northern Ghana, in which households of index participants received rations of multiple micronutrient-fortified bouillon cubes (vitamins A and B12, folic acid, iron, zinc and iodine) or control bouillon cubes (iodine) for nine months. One NIHM (≥ 15 years) per household ($n=1047$) was randomly selected for the study, and background characteristics were collected. During the first two months of the intervention (months 1–2; early, $n = 731$) and the final two months before exit (months 7–9; late, $n = 796$), quantitative data were collected using a 29-item questionnaire,

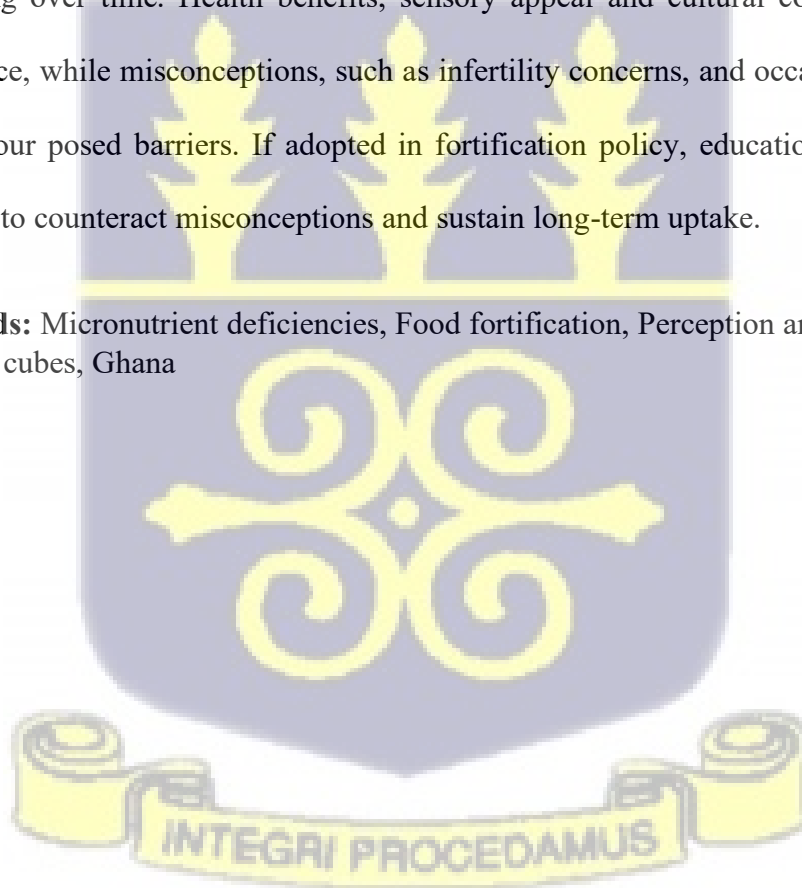
most of which elicited responses on a five-point Likert-scale with response options ranging from 1 (completely disagree) to 5 (completely agree). A total of 18 items (8 for perception, 10 for acceptance) were validated using factor analysis and used to compute composite scores (normalised weighted sums) for perception and acceptance at both time points, with higher scores indicating greater perception or acceptance. Bayesian linear mixed-effects models were used to assess changes in perception and acceptance, as well as associated household- and individual-level factors. Twenty-four focus group discussions were conducted at the intervention midpoint (months 4–5) and analysed using Braun and Clarke’s six-phase framework, together with Latent Dirichlet Allocation, to explore cultural, sensory, economic and health-related influences.

Results: The mean age of participants was 40 ± 14.7 years, with 59% being female. Perception increased significantly over time (3.4 ± 1.1 to 4.1 ± 0.6 ; adjusted mean difference (aMD) = 0.74, 95% CrI: 0.63–0.86). In contrast, acceptance remained consistently high throughout the study (4.59 ± 0.38 to 4.58 ± 0.35 ; aMD = -0.01 , 95% CrI: -0.06 – 0.04), with no differences observed between intervention groups. Perception scores were significantly lower among formal employees compared with farmers ($\beta = -0.48$, 95% CrI: -0.73 – 0.22) and significantly higher among wives ($\beta = 0.54$, 95% CrI: 0.32 – 0.76), sons or daughters ($\beta = 0.45$, 95% CrI: 0.21 – 0.69), parents ($\beta = 0.31$, 95% CrI: 0.07 – 0.55) and in-laws or siblings ($\beta = 0.40$, 95% CrI: 0.16 – 0.64), relative to household heads. Perception increased over time, with greater increases observed among formal employees (interaction $\beta = 0.64$, 95% CrI: 0.29 – 0.99) and small business owners (interaction $\beta = 0.24$, 95% CrI: 0.02 – 0.46). Acceptance scores were significantly higher among males ($\beta = 0.05$, 95% CrI: 0.01 – 0.09) and small business owners ($\beta = 0.06$, 95% CrI: 0.01 – 0.11). Urban

residence was associated with lower acceptance ($\beta = -0.08$, 95% CrI: -0.12 – 0.04), while severe food insecurity ($\beta = 0.12$, 95% CrI: 0.05 – 0.19) and higher socio-economic status ($\beta = 0.03$, 95% CrI: 0.01 – 0.05) were positively associated with acceptance. From the focus group discussions, key drivers of bouillon acceptance included perceived health benefits, sensory appeal, and cultural compatibility with traditional meals; barriers to acceptance included misconceptions about bouillon cubes causing long-term infertility in males, and occasional changes in food colour.

Conclusion: The study-supplied bouillon cubes were highly accepted, with perceptions improving over time. Health benefits, sensory appeal and cultural compatibility drove acceptance, while misconceptions, such as infertility concerns, and occasional changes in food colour posed barriers. If adopted in fortification policy, educational initiatives are essential to counteract misconceptions and sustain long-term uptake.

Keywords: Micronutrient deficiencies, Food fortification, Perception and acceptance, Bouillon cubes, Ghana



Introduction

Micronutrient deficiencies (MNDs) remain a major global health issue, disproportionately affecting low- and middle-income countries (LMICs) and leading to population-specific adverse outcomes. Among women of reproductive age, deficiencies in iron, folate, and vitamin B12 contribute to anaemia, fatigue, and poor pregnancy outcomes, including preterm birth and low birth weight (Black et al., 2013; WHO, 2024a). In pre-school children, deficiencies in iron, iodine, vitamin A, and zinc impair cognitive development, growth, and immune function, thereby increasing susceptibility to infections and hindering early learning potential (Prado & Dewey, 2014; Stevens, Paciorek, et al., 2022; Wells et al., 2020).

In Ghana, the northern belt has a higher prevalence of micronutrient deficiencies and anaemia, affecting over 40% of women of reproductive age (WRA) and pre-school children (PSC). This burden is primarily linked to inadequate nutrient intake, infections, and socio-economic disparities (Abizari, Azupogo, et al., 2017; Petry et al., 2021; UNICEF, 2017; Wegmüller et al., 2020). Economically, these deficiencies cost Ghana about US\$100 million annually in healthcare expenses and lost productivity (USAID Advancing Nutrition, 2023). Addressing MNDs remains important for improving health and aligns with global public health goals, such as Sustainable Development Goal (SDG) 2, which aims to eliminate malnutrition by 2030 (United Nations, 2015).

Food fortification presents a cost-effective strategy for reducing MNDs (GAIN, 2024; WHO, 2024b). Large-scale food fortification (LSFF) programmes, such as fortifying wheat flour and cooking oils, have reduced MND prevalence in several regions across LMICs (Keats et al., 2022; Olson et al., 2021; WHO, 2024b). However, in northern Ghana, fortification efforts are limited, with only 36% of cooking oils and 6% of wheat flour

samples meeting fortification standards (University of Ghana et al., 2017). Key challenges include weak policy enforcement, limited industrial capacity, high production costs, inadequate supply chains, and low consumer awareness and demand, particularly in rural areas (Nyumuah et al., 2012; UNICEF, 2017). This forms the basis for innovative and culturally appropriate strategies to address MNDs, particularly in settings with inadequate dietary diversity.

Bouillon cubes, which are regularly consumed condiments by over 90% of households in northern Ghana, offer a unique vehicle for micronutrient fortification (Abizari, Dold, et al., 2017; Kumordzie et al., 2021; Wessells et al., 2024). The centralised production of bouillon cubes by a few large companies ensures regulatory oversight and consistent fortification standards (GAIN, 2023b; Moretti et al., 2018). Modelling studies involving countries in sub-Saharan Africa and Asia have demonstrated that fortifying bouillon cubes with micronutrients such as iron, iodine, vitamin A, and zinc can improve micronutrient status of women and children (Eilander et al., 2023; Thompson et al., 2024; Vosti et al., 2020).

However, the success of micronutrient fortification programmes hinges not only on nutritional impact (GAIN, 2023a). Household members' perceptions (including opinions and attitudes) and acceptance can significantly influence fortification interventions (Christian et al., 2016; Katenga-Kaunda et al., 2022; Keats et al., 2019). While previous studies have explored consumer acceptance of intervention products among direct participants and caregivers (Adu-Afarwuah et al., 2008; Creed-Kanashiro et al., 2016; Kyei-Arthur et al., 2024; Kyei-Arthur et al., 2020), the broader household context, particularly the role of non-index household members (NIHMs) in food preparation and

decision-making, remains under-researched (GAIN, 2023a; Lamstein et al., 2014). Investigating this group allows for a detailed understanding of acceptance and potential challenges that may not be visible in studies focused solely on direct participants. Concerns such as taste, aroma, cost, and misconceptions may hinder the uptake of fortified products (Baker et al., 2022; Fiorentini et al., 2020; Miassi et al., 2022). For example, in northern Ghana, some adolescent girls rejected iron and folic acid supplements due to the belief among their caregivers and some opinion leaders that these supplements could cause infertility (Gosdin et al., 2021).

Therefore, this study, nested within the Condiment Micronutrient Innovation Trial (CoMIT), examines changes in perception and acceptance of the study-supplied bouillon cubes over time. It further explores the drivers and barriers influencing these changes among non-index household members (NIHMs), including household heads, wives, children, parents, and siblings of the household heads aged 15 years or older who were not enrolled as primary trial participants.

Methods

Overview of the Condiment Micronutrient Innovation Trial (CoMIT) randomised controlled trial (RCT)

The CoMIT RCT compared the effects of household use of bouillon cubes fortified with multiple micronutrients against cubes fortified with iodine alone. The multiple micronutrients-fortified cubes delivered iodine (30 µg as potassium iodate), vitamin A (200 µg), folic acid (80 µg), vitamin B12 (1.2 µg), iron (4 mg as ferric pyrophosphate) and zinc (3 mg as zinc oxide) per cube, whereas the control cubes contained only 30 µg of iodine. Primary endpoints were haemoglobin (Hb) concentration and selected

micronutrient biomarkers among non-pregnant, non-lactating WRA (15–49 years; $n = 1\,028$) and pre-school children (2–5 years; $n = 690$), with breast milk micronutrient levels assessed in lactating women 4–18 months postpartum ($n = 690$). Full methodological details are reported in (Engle-Stone et al., 2023).

The CoMIT was a double-blind randomised trial carried out in sixteen sites defined by the Ghana Statistical Service across the Kumbungu and Tolon districts of northern Ghana, spanning urban, rural and semi-urban communities. Randomisation took place at the household level via a computer-generated block scheme (blocks of four or eight). Participants drew their assignment from opaque, numbered envelopes linked to study codes.

Eligibility criteria for WRA included the absence of severe illness, intention to remain in the study area, a negative malaria rapid diagnostic test, a C-reactive protein < 5 mg/L at the radial immunodiffusion screening, and Hb ≥ 80 g/L at both screening and baseline. Pre-school children were eligible if they had a mid-upper arm circumference ≥ 11.5 cm at recruitment, Hb ≥ 70 g/L, a weight-for-height z-score ≥ -3 SD, and no signs of bilateral pitting oedema at baseline. Households agreed to use only the provided cubes and to have no known allergies to the ingredients.

Trained fieldworkers, in collaboration with local health volunteers, recruited participants through door-to-door visits using a random walk method. After baseline assessments, study cubes were distributed every two weeks in quantities based on household size and estimated use, with participants instructed to use only the supplied cubes for cooking. Adherence was monitored through unannounced spot checks and structured questionnaires. Ethical approval was granted by the Ghana Health Service

Ethical Review Committee (GHS ERC ID: 024/11/21), the University of California, Davis Institutional Review Board (IRB ID: 1837253) and the Ghana Food and Drugs Authority (Certificate no FDA/CT/2213 (1)). The trial is registered at ClinicalTrials.gov (NCT05178407) and the Pan-African Clinical Trials Registry (PACTR202206868437931).

Study design and data collection time points– current study

This study, nested within the CoMIT project, used a longitudinal mixed-methods design, with quantitative data collected at three time points and complemented by a round of focus group discussions (FGDs). Quantitative data were first collected at the pre-intervention time point (T0), within three weeks of enrolment from NIHMIs across all three index participants' households (LW, WRA, and PSC), before the distribution of the study bouillon cubes. At the early intervention time point (T1), quantitative data were collected within the first two months after households received the study bouillon cubes, involving NIHMIs from households of WRA and PSC. At the late intervention time point (T2), quantitative data were collected within the final two months of the trial, involving NIHMIs from households of WRA and PSC. In addition, midpoint focus group discussions (FGDs) were held 4–5 months into the intervention. Data collection spanned January 2023 to May 2024.

Participants and Recruitment Procedure

Eligible participants were NIHMIs aged ≥ 15 years from households enrolled in the primary CoMIT RCT. Inclusion criteria included residing in the household for ≥ 1 month prior to

enrolment, regularly sharing meals with index participants, intending to remain for the trial duration, and providing informed consent or assent with caregiver consent (for ages 15–17). Exclusion criteria included having known allergies to bouillon cube ingredients or sensory-related medical conditions. NIHMs were eligible if at least one index participant was enrolled in the household and remained throughout the RCT.

Recruitment occurred within a three-week window after the index participant had consented to the primary CoMIT RCT and before distribution of the study bouillon cubes. Eligible NIHMs were identified using household rosters compiled during index recruitment. In households with a single eligible NIHM, that individual was selected. Where multiple NIHMs were eligible, one was randomly selected using a Kish table (Nemeth, 2002). If the selected individual declined and other eligible members remained, random selection was repeated.

Recruitment was carried out by five trained interviewers fluent in English and Dagbani, under the supervision of field supervisors. Given limited literacy among participants, study information was delivered verbally in Dagbani. Comprehension was assessed using five key questions, and clarifications were provided before enrolment. Consent was obtained via signature or thumbprint, and each participant was assigned a unique identifier linked to their index participant.

For the qualitative component, FGD participants were purposively selected based on sex, age group (<50 and ≥50 years), and household bouillon cube code (H24, K95, L63, M78). FGDs were conducted separately for males and females, with each group including participants from all four cube codes.

Pretesting and Quantitative Data Collection

The questionnaire was pre-tested with 18 purposively selected adults (20–70 years) from two rural communities located 15–20 km from the nearest study sites. These communities, which shared similar cultural and dietary practices with the study population, were excluded from the main data collection to avoid contamination. Participants included household heads, primary cooks, and other adult household members. Feedback was used to revise item clarity, sequencing, and layout (Lenzner, 2024). Participants informed pretesting and adaptation of data collection instruments but were not involved in the trial design or analysis.

Ten trained fieldworkers administered the final questionnaire electronically using SurveyCTO. Field supervisors conducted daily quality control reviews. Baseline data included demographic characteristics for NIHM; a household asset-based socioeconomic status index; and food insecurity, measured using the Household Food Insecurity Access Scale (HFIAS) (Coates et al., 2007). Baseline household commercial bouillon use in the prior 30 days was also recorded, estimated in grams per capita per day using a modified version of the Fortification Assessment Coverage Toolkit (FACT) approach (Friesen et al., 2019). These variables were extracted from the household-level questionnaire administered during the trial.

At T1 and T2, perception was defined as NIHM's opinions and attitudes towards the health benefits, safety, and appropriateness of the study cubes, while acceptance referred to their willingness to consume and incorporate the cubes into household meals. These constructs were measured using a researcher-developed questionnaire comprising 26 Likert-scale items (1 = completely disagree to 5 = completely agree) and three

categorical preference items. Composite scores (range: 1–5, with higher scores indicating more positive perceptions or greater acceptance) were derived for perception (8 items) and acceptance (10 items) from a validated 18-item instrument.

Qualitative Component: Focus group discussions (FGDs)

Twenty-four FGDs were conducted with NIHMs (n=157), each comprising 6–8 participants. Groups were stratified by sex (12 male and 12 female), age group (<50 vs. ≥ 50 years), and intervention allocation code, which indicated whether the household had been randomised to receive multiple-micronutrient-fortified or control (iodine-only) bouillon cubes. Each group included participants from all allocation codes. FGDs were conducted in Dagbani by trained facilitators using a translated and pre-tested guide grounded in the Theory of Planned Behaviour (TPB) (Ajzen, 1991) and Health Belief Model (HBM) (Rosenstock, 1974). Topics included taste and smell, cultural compatibility, perceived health benefits, economic utility, product preferences, and barriers. Sessions lasted approximately two hours and were audio-recorded, with note-takers documenting nonverbal cues. Facilitators held debriefs after each FGD to ensure consistency.

Creation of perception and acceptance composite scores (Outcome variable)

The primary outcome variables were composite scores representing NIHMs perception and acceptance of the fortified bouillon cubes supplied in the study. These scores were derived from a structured, psychometrically validated questionnaire developed in the first study manuscript (see **Objective 1 / Chapter 5**). Confirmatory factor analysis (CFA) supported a two-factor model: perception (8 items; Cronbach's $\alpha = 0.71$) and acceptance (10 items;

Cronbach's $\alpha = 0.72$). Item responses were weighted by their standardised CFA loadings (see **Table 6.1**), aggregated and normalized to generate continuous composite scores ranging from 1 (lowest) to 5 (highest). A higher perception or acceptance score indicates a more positive and favourable outcome.

Scores were computed separately for the early (T1) and late (T2) intervention phases. All retained items met the minimum standardised loading threshold of 0.40, and both composite scores were treated as continuous variables in subsequent analyses. Full validation procedures and psychometric properties are described in **Objective 1 / Chapter 5**. No formal harms or adverse events were pre-specified, as this study focused on perception and acceptance outcomes; however, no adverse events related to bouillon consumption were reported during the study.

Table 6.1 Results of the Standardised factor loadings from the CFA used to create perception and acceptance composite score to early and late time point¹

Perception		Acceptance	
Items	Standardised factor loadings	Items	Standardised factor loadings
Q1	0.770	Q2	0.525
Q3	0.756	Q5	0.476
Q4	0.719	Q10	0.486
Q6	0.483	Q16	0.538
Q23	0.520	Q17	0.606
Q24	0.464	Q18	0.578
Q26	0.743	Q20	0.607
Q27	0.756	Q25	0.553
		Q28	0.574
		Q29	0.692

¹Standardised factor loading of ≥ 0.4 is deemed acceptable

Sample size determination and justification

A total of 1,047 participants (one NIHM per household in the CoMIT RCT) were enrolled at the pre-intervention timepoint. At T1 and T2, 731 and 796 respondents completed interviews, respectively, with 676 providing complete data for both timepoints and forming the analytic sample.

Sample size considerations were based on the parent CoMIT RCT, which was powered to detect a minimum standardized mean difference of 0.26 (Cohen's d) in primary outcomes at $\alpha=0.05$ and 80% power (Engle-Stone et al., 2023). Applying this effect size to the present study indicated that 396 participants (198 per group) would be sufficient to detect a between-group difference of similar magnitude. The analytic sample of 676 complete cases exceeded this threshold, ensuring adequate statistical power for both within-subject and between-group comparisons. Although no established minimal important difference exists for perception or acceptance scores, a standardized mean difference of 0.26 represents a small-to-moderate, and likely meaningful, change in behavioral constructs in nutrition interventions (Cohen, 2013).

Data analysis

Normality of perception and acceptance scores was assessed using histograms, Q-Q plots, and the Shapiro-Wilk test. Although the Shapiro-Wilk test was significant for acceptance ($p = 0.047$), consistent with its sensitivity in large samples, visual inspection indicated approximate normality. Transformations (natural log and square root) did not improve the distribution of acceptance scores. Therefore, untransformed scores were retained for all analyses, in line with recommended practices for large samples and robust modelling

approaches (Field, 2024; Ghasemi & Zahediasl, 2012; Williams et al., 2013). Continuous predictors were standardised (mean = 0, SD = 1) for interpretability of model coefficients (Fox & Weisberg, 2018). Variance inflation factors (VIF) indicated no multicollinearity (all VIF < 5) for predictors. Descriptive statistics including means, standard deviations (SD) counts, and percentages were computed for all variables.

Bayesian linear mixed-effects models were used for all inferential analyses due to their flexibility in handling repeated measures, robustness to minor deviations from normality, and ability to incorporate uncertainty via prior distributions and random effects (Chen et al., 2022; Gelman et al., 2020; van de Schoot et al., 2021). This approach was adopted after frequentist mixed-effects models exhibited singular fits and convergence failures for random intercepts, whereas the Bayesian framework yielded stable estimation and full model convergence. Group blinding was maintained throughout to minimise bias. Analyses were conducted in R (version 4.3.1) using the *brms* (v2.22.0) and *bayesplot* (v1.11.1) packages (Bürkner, 2017, 2021; Gabry et al., 2019). All final models were estimated via Hamiltonian Monte Carlo sampling with four chains of 4,000 iterations each, including 1,000 warm-up iterations. Weakly informative priors were specified: Normal(0, 5) for fixed effects and Student t(3, 0, 5) for intercepts. Convergence was assessed using R-hat statistics (< 1.01), effective sample sizes, and trace plots. Posterior predictive checks (via *pp_check*) supported model adequacy. Results are reported as posterior means with 95% credible intervals (CrI); CrIs excluding zero were interpreted as statistically meaningful (Gelman et al., 2020; van de Schoot et al., 2021).

To evaluate the change in perception and acceptance scores from T1 to T2, separate models were specified for these outcomes. Initial models included fixed effects for time

(T1 vs. T2), group (multiple micronutrient-fortified vs. iodine-only fortified bouillon cubes), and their interaction (time $\times$ group), along with a random intercept for participant ID. As the interaction and group effects were non-significant for any of the outcomes, the final models retained only time as a fixed effect and participant ID as a random intercept. These models were treated as unadjusted models.

Subsequently, potential confounders were identified for each outcome using bivariate associations: Pearson correlations for continuous variables, independent t-tests for binary variables, and one-way ANOVA for categorical variables with three or more levels. Covariates with $p < 0.10$ were retained for adjusted models (Hosmer Jr et al., 2013; Tabachnick et al., 2019). The adjusted perception model included baseline household bouillon consumption (g/capita/day), district (Kumbungu vs. Tolon), HFIAS (categorised), and the participant's relationship to the household head (categorised). The adjusted acceptance model included household size, HFIAS, sex, residence and religion.

To examine associations between perception or acceptance scores and individual- or household-level factors, separate models were specified for each outcome. Each model included fixed effects for time, group, and pre-specified predictors, with a random intercept for participant ID to account for repeated measures. The base model was specified as:

Score $\sim$ predictors + group + time + (1 | Participant ID).

To assess potential time-varying associations, an extended model included interaction terms between each predictor and time:

Score $\sim$ predictors + time + time $\times$ predictor + (1 | Participant ID).

Pre-specified predictors were selected based on theoretical relevance (Chowdhury & Turin, 2020). Individual-level factors included sex (female vs. male), age (continuous),

occupation (farming, homemaker, small business owner, or formal employment), relationship to the household head (head, wife, child, in-law or sibling, or parent), cooking responsibility (never, primary, or secondary/occasional), ethnicity, religion and educational level. Household-level factors comprised household size (continuous), baseline household bouillon consumption in grams per capita per day (continuous), food security status based on the HFIAS (categorised as food secure, mildly food insecure, moderately food insecure, or severely food insecure), socio-economic status (continuous), residential strata (rural vs. urban), district (Tolon vs. Kumbungu), and sex of the household head (female vs. male). All categorical variables were dummy-coded, where the first category was used as the reference group. Group assignment (study arms) was included as a covariate in all models.

Model selection was conducted by comparing the base and interaction models using predictor significance and overall model performance. While all predictors were pre-specified, variables that showed no meaningful statistical association and lacked practical relevance in preliminary models were excluded from the final model through iterative refinement. Model fit was assessed using posterior predictive checks, the Widely Applicable Information Criterion (WAIC), and Leave-One-Out Cross-Validation (LOO-CV) (Vehtari et al., 2017). After several iterations for each outcome, model fit was compared between a main effects model and an interaction model using the Leave-One-Out Information Criterion (LOOIC). For perception scores, the interaction model showed better fit (LOOIC = 3757.1, SE = 62.4) than the main effects model. For acceptance scores, the main effects model was preferred, with a lower LOOIC (709.8, SE = 3.1) compared to the interaction model, indicating that interaction terms did not improve fit for this outcome.

Sensitivity analyses were performed using alternative prior specifications, which produced consistent results and confirmed the robustness of the findings (see **Supplemental Tables 1a and 1b**).

Thematic analysis approach for focus group discussions (FGDs)

All 24 FGDs, conducted in Dagbani, were transcribed into English. Thereafter, the transcripts of 12 FGDs were randomly selected and reviewed by two independent master's degree holders fluent in Dagbani and English for accuracy, while transcripts of 6 FGDs were back-translated to verify the preservation of meaning (Ozolins et al., 2020). Theme saturation was achieved by the 22nd FGD, with no new themes emerging thereafter, confirming sample adequacy.

A preliminary codebook was manually developed by the primary researcher (FKK) and an external researcher (TF) using Braun and Clarke's six-step framework (Braun & Clarke, 2021), based on six transcripts. Any discrepancies in coding were resolved through recoding and collaborative discussion. Inter-coder reliability (ICR) was assessed by having FKK and an external researcher (TF) independently code the same transcripts. Cohen's Kappa and percentage agreement were used to evaluate coding consistency, with values ≥ 0.7 considered indicative of substantial agreement (Hsieh & Shannon, 2005). An average Cohen's Kappa of 0.96 and a percentage agreement of 97.6% were achieved across themes (see **Table 6.2**). No further modifications were made to the codebook following this reliability check.

The full dataset was structured in Microsoft Excel, with each speaker represented in a single row. Metadata variables included participant pseudonym, sex, age, education

level, and intervention group. Transcripts were imported into R (version 4.3.3) for preprocessing, which included tokenization, stop-word removal, and lemmatization (Chai, 2023; Hickman et al., 2022), using the *tidytext*, *tm* and *topicmodels* packages (Feinerer et al., 2008; Grün & Hornik, 2011; Silge & Robinson, 2016).

Each transcript was treated as a separate document for Latent Dirichlet Allocation (LDA) topic modelling (Chauhan & Shah, 2021). Although LDA is often applied to larger corpora, prior studies support its use with smaller, information-rich qualitative datasets (Blei et al., 2003; Roberts et al., 2014; Romero et al., 2024). In this study, each transcript averaged approximately 3,000 words, providing adequate lexical variability for stable topic identification. The optimal number of topics ($k = 6$) was selected based on the highest model coherence score (Cv) and manual interpretability checks, following recommended approaches for topic model evaluation (Röder et al., 2015). The combined use of inductive manual coding and unsupervised topic modelling strengthened both depth and transparency of the analysis, consistent with emerging frameworks for combining human interpretation with computational tools (Chen et al., 2018; Nelson, 2020).

Topics derived from the LDA were systematically compared to the manually generated themes. Several topics, including affordability, health concerns, and cultural familiarity, showed strong correspondence with themes identified through manual coding. An additional theme “practical experience” with the study bouillon cubes emerged exclusively through topic modelling. This theme was incorporated into the final thematic framework following transcript re-examination and agreement among the research team.

To further examine emotional and evaluative content, sentiment analysis was conducted using the National Research Council (NRC) lexicon (Mohammad & Turney,

2013; Nandwani & Verma, 2021), which classifies terms by emotional valence and polarity.

Findings from the thematic analysis, topic modelling, and sentiment analysis were subsequently integrated with the quantitative dataset during interpretation, consistent with the principles of a convergent mixed-methods design (Creswell & Clark, 2017).

Table 6.2. Intercode reliability (ICR) calculated using Cohen's kappa and agreement (%)¹

Segment	(Cohen's Kappa)	Percent Agreement
1. Health benefits of the study cubes	1.00	100%
2. Sensory appeal of the study cubes (flavour and taste)	1.00	100%
3. Practical experiences of the study cubes	0.96	97.2%
4. Economic benefits of the study cubes	1.00	100%
5. Cultural compatibility and cooking habits	0.98	99.2%
6. Sensory challenges of the study cubes	0.95	97.3%
7. Long-term side effects	0.89	91.7%
8. Darkening of soup with some food such as green leafy soups	0.93	95.4%
Average total	0.96	97.6%

¹Footnotes: ICR score calculated in R-programming 4.3.0. Average ICR represents the average final ICR of n=6 focus group discussion (FGD) transcripts that were independently coded by 2 coders. See FGD guide in Supplemental Appendix for full descriptions of FGD questions.

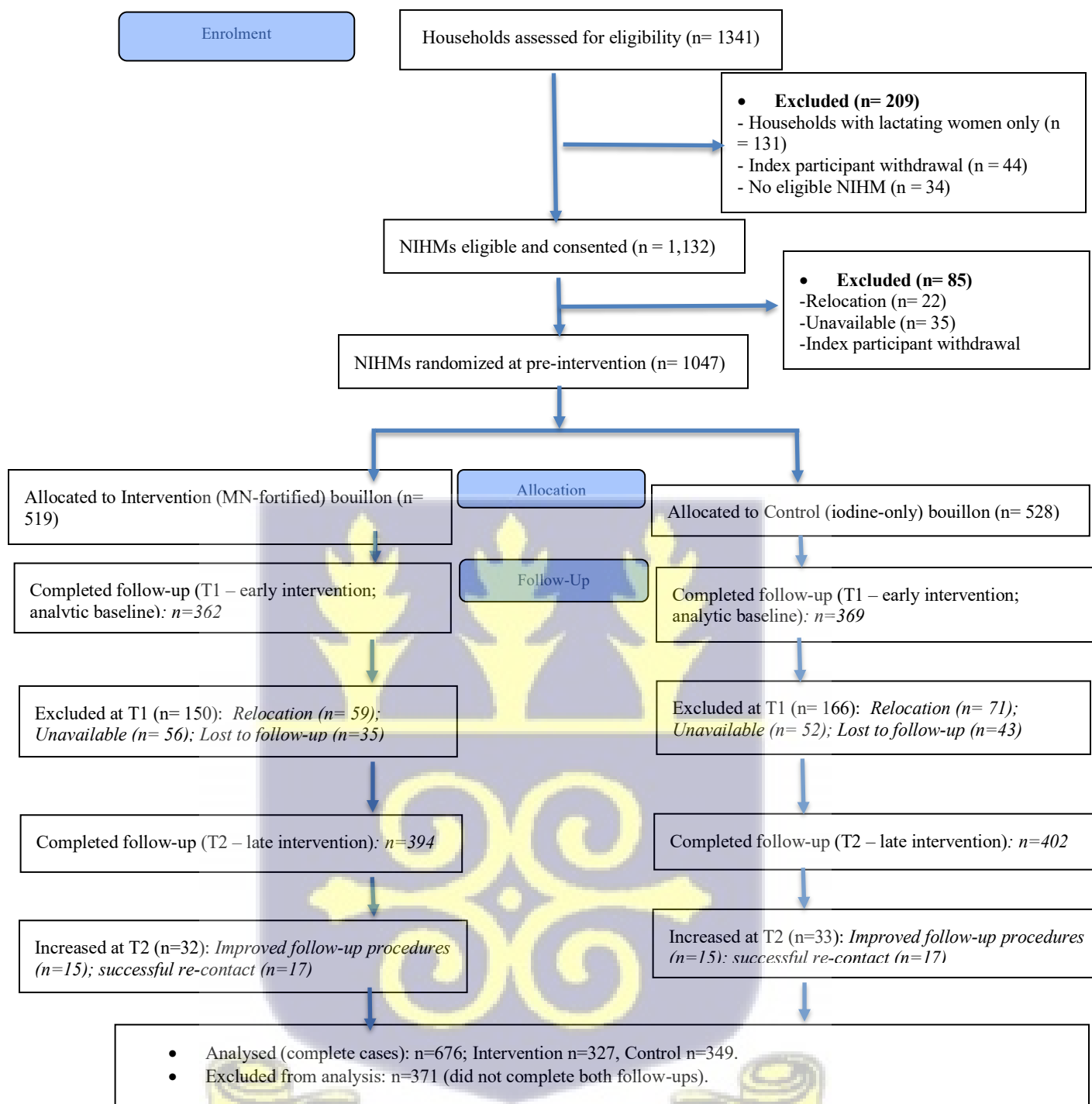


Results

Figure.1 shows the flow of households and NIHMs through the trial. Of the 1,341 households assessed for eligibility, 1,132 were eligible and consented. A total of 1,047 NIHMs were randomised to receive either multiple-micronutrient–fortified bouillon ($n = 519$) or iodine-only bouillon ($n = 528$). At T1 (early intervention; analytic baseline), 362 intervention and 369 control NIHMs completed follow-up, with exclusions due to relocation, unavailability, or loss to follow-up. At T2 (late intervention), 394 intervention and 402 control NIHMs completed follow-up, with increases attributable to improved re-contact and follow-up procedures. Overall, 676 complete cases (327 intervention, 349 control) were analysed, while 371 NIHMs were excluded from analysis due to incomplete follow-up. The analytic sample included 676 NIHMs with complete data at both T1 and T2, comprising 327 in the intervention arm and 349 in the control arm.

Baseline characteristics of participants with complete data at both time points ($n = 676$) were compared with those who did not complete follow-up ($n = 371$). No statistically significant differences were observed in age, sex, occupation, randomization group, rural/urban strata, or district of residence (all $p > 0.05$), suggesting minimal attrition bias (see **S4 Table**).

Participant recruitment took place between January and May 2023. The T1 (early intervention; analytic baseline) survey was conducted approximately one month after cube distribution began, and the T2 (late intervention) survey was conducted seven months later, at the end of the intervention period.



Note: NIHMs = Non-Index Household Members. T1 = early intervention; T2 = late intervention.

Figure.1. CONSORT 2025 flow diagram of household and NIHMs participation through the trial.

Background characteristics

Table 6.3 summarizes the background characteristics of the study participants at recruitment. The mean age of participants was 39.5 years in the intervention group and 40.5 years in the control group. Women comprised the majority in both groups (59.0% vs. 59.1%). Most participants were wives of the household head (37.0% vs. 38.6%) or reported other relationships such as children, in-laws, or siblings (26.2% vs. 20.5%). Approximately three-quarters of participants in both arms had no formal education, and nearly all were of Dagomba ethnicity (>98%) and Muslim (>98%). Agriculture and small business were the most common occupations in both groups. Household characteristics were also comparable, with mean household size of 11.4 in the intervention group and 11.3 in the control group. Food insecurity was prevalent, with more than half of households classified as moderately or severely food insecure in both groups. Average baseline household bouillon consumption was 3.2 g/capita/day in the intervention arm and 2.9 g/capita/day in the control arm.

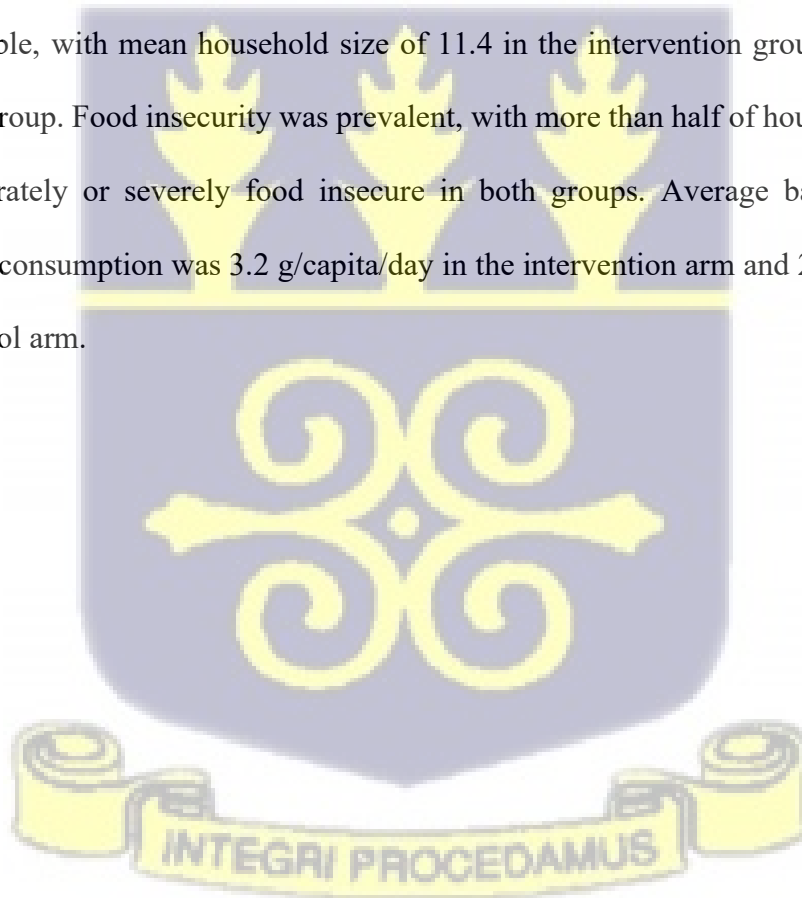


Table 1. Baseline household- and individual-level characteristics of non-index household members by randomisation group

Variable	Intervention (n=519) Frequency (%)	Control (n=528) Frequency (%)
Age, years (<i>mean</i> $\pm$ <i>SD</i>)	39.5 $\pm$ 14.7	40.5 $\pm$ 14.6
Sex		
Male	213 (41.0)	216 (40.9)
Female	306 (59.0)	312 (59.1)
Relationship with HH		
Self	130 (25.0)	165 (31.2)
Wife of HH	192 (37.0)	204 (38.6)
Parent of HH	61 (11.8)	51 (9.7)
Others ²	136 (26.2)	108 (20.5)
Household cooking role		
Never cook	207 (39.9)	220 (41.7)
Primary cook	196 (37.8)	186 (35.2)
Secondary/occasional	116 (22.4)	122 (23.1)
Educational Level		
No formal education	381 (73.4)	399 (75.6)
Basic education	67 (12.9)	66 (12.5)
Senior High School or higher	71 (13.7)	63 (11.9)
Ethnicity		
Dagomba	517 (100.0)	525 (100.0)
Religion		
Islam	513 (98.8)	519 (98.3)
Others ⁴	6 (1.2)	9 (1.7)
Occupation		
Agricultural/Farming	236 (45.5)	239 (45.3)
Homemaker	84 (16.2)	94 (17.8)
Self-employed (Small Business owners)	158 (30.4)	155 (29.4)
Government/private employees (formal employees)	41 (7.9)	40 (7.6)
District		
Kumbungu	248 (47.8)	240 (45.5)
Tolon	271 (52.2)	288 (54.5)
Strata		
Rural	264 (50.9)	279 (52.8)
Urban	255 (49.1)	249 (47.2)
Household Head Education Level		
No formal education	398 (77.7)	405 (77.7)
Primary	55 (10.7)	52 (10.0)
Secondary or higher	59 (11.5)	64 (12.3)
Household Head Sex		
Male	482 (93.6)	516 (97.7)
Female	33 (6.4)	12 (2.3)
Household size (<i>mean</i> $\pm$ <i>SD</i>)	11.4 $\pm$ 5.9	11.3 $\pm$ 5.8

Household Food Insecurity (HFIAS)

Food secure	210 (40.5)	214 (40.5)
Mild food insecure	94 (18.1)	80 (15.2)
Moderate food insecure	164 (31.6)	190 (36.0)
Severe food insecure	51 (9.8)	44 (8.3)
Baseline household bouillon consumption (g/per capita/day) (mean $\pm$ SD)	3.2 $\pm$ 7.4	2.9 $\pm$ 4.0

Note:

Participants include non-enrolled household members aged 15 years and older from households participating in the Condiment Micronutrient Innovation Trial (CoMIT).

Household food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS) (Coates et al., 2007).

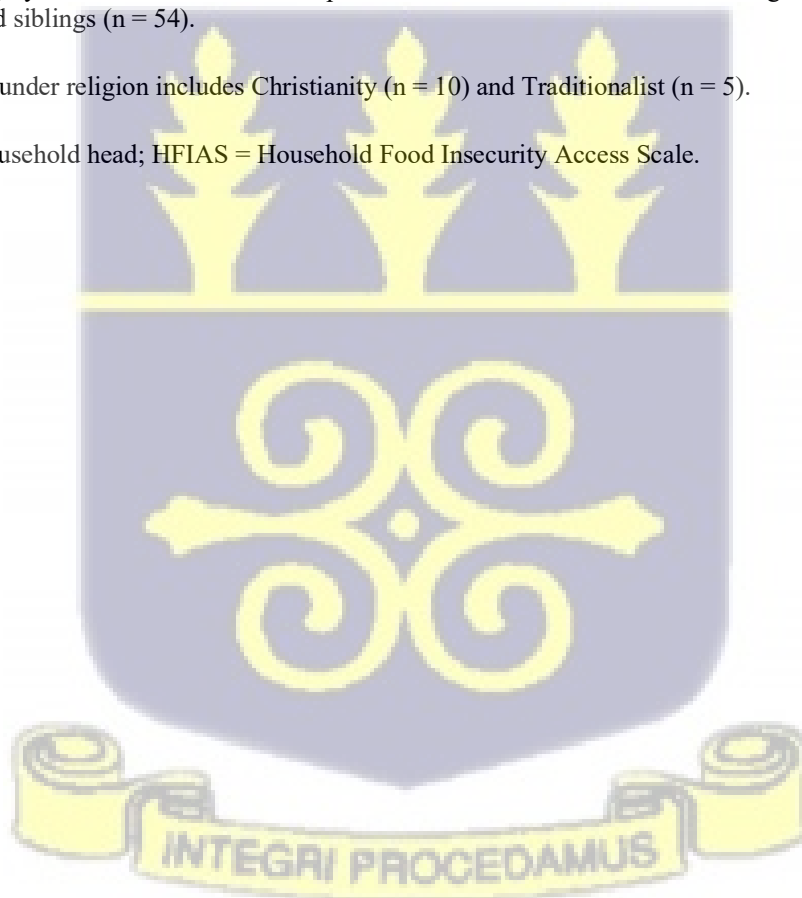
Baseline household bouillon consumption was calculated as total grams used per day divided by household size, resulting in grams per capita per day).

Values are mean $\pm$ SD for continuous variables and n (%) for categorical variables. No statistical tests of baseline differences were performed, consistent with CONSORT recommendations.

The category “Others” under relationship to household head includes sons or daughters (n = 102), daughters-in-law (n = 88), and siblings (n = 54).

“Others” under religion includes Christianity (n = 10) and Traditionalist (n = 5).

HH = household head; HFIAS = Household Food Insecurity Access Scale.



Change in perception and acceptance of the intervention bouillon cubes among non-enrolled household members in the CoMIT project.

A. Change in perception

Table 6.4 presents the change in perception scores from T1 to T2. The mean perception score increased from 3.4 (SD = 1.1) at T1 to 4.1 (SD = 0.6) at T2. As scores range from 1 to 5, with higher values reflecting more favorable perception, this increase represents a notable shift over time. In the unadjusted model, the estimated mean difference was ($\beta = 0.72$; 95% CrI = [0.62, 0.86]). In the adjusted model, the estimated mean difference was ($\beta = 0.74$; 95% CrI = [0.63, 0.86]). The interaction between time point and group was also not significant ($\beta = -0.03$, 95% CI [-0.19, 0.15]), indicating that changes in perception were consistent across intervention groups.

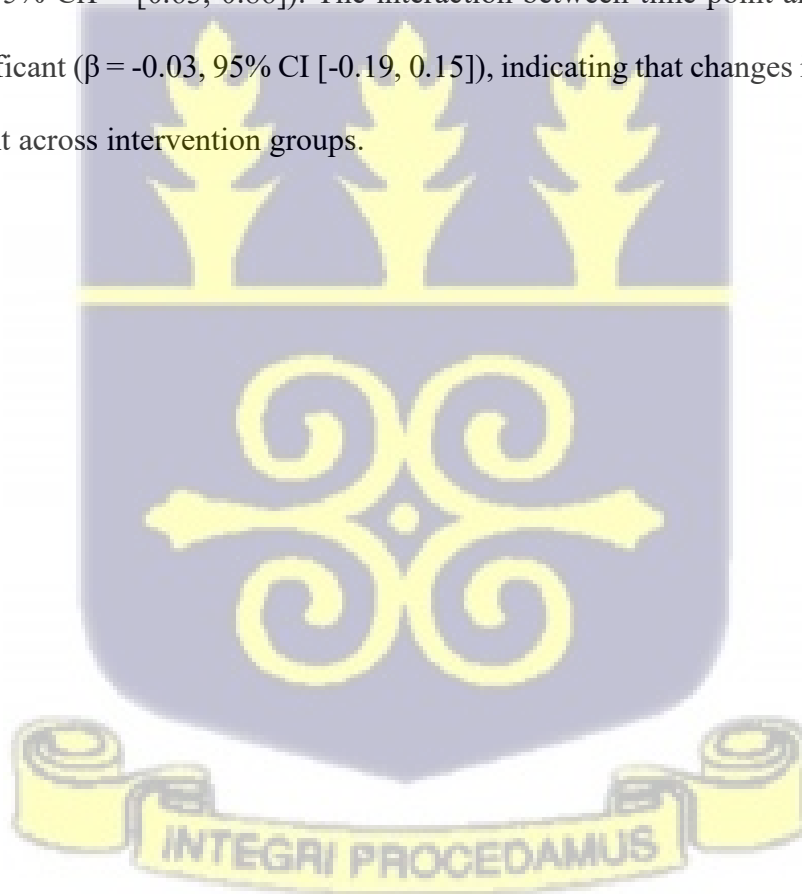


Table 6.4. Change in perception of study-supplied bouillon cubes among non-index household members between early (T1) and late (T2) intervention phases

Variables	Posterior Mean Estimate (β)	95% Credible Interval (CrI)	Raw Mean (Mean $\pm$ SD)
Unadjusted model			
Time point (T2 vs. T1)	0.72	0.62, 0.86	T1: 3.4 $\pm$ 1.1; T2: 4.1 $\pm$ 0.6
Random intercept			
SD (participant intercept)	0.05	0.00, 0.13	NA
Adjusted model			
Time point (T2 vs. T1)	0.74	0.63, 0.86	
SD (participant intercept)	0.05	0.00, 0.14	NA

Note:

Posterior mean (β) values represent model-estimated mean differences in perception scores. Estimates were obtained using Bayesian linear mixed-effects models with random intercepts for participants. A 95% credible interval (CrI) that does not include 0 indicates statistical significance (*).

Study-supplied bouillon cubes included either multiple micronutrient-fortified cubes (containing vitamins A and B12, folic acid, iron, zinc, and iodine) or control cubes fortified with iodine only.

T1 represents the early intervention time point (data collected during the second month of household exposure), and T2 represents the late intervention time point (data collected during the final two months of the nine-month intervention).

Perception scores range from 1 to 5, with higher values indicating more favorable perceptions of the fortified bouillon cubes.

The adjusted model includes covariates for district of residence, participant's relationship to the household head, baseline household bouillon consumption (grams per capita per day), participant's role in household cooking, and sex of the household head.



B. Change in acceptance

Table 6.5 presents the change in acceptance scores from T1 to T2. Mean scores remained high across both time points, with a score of 4.59 (SD = 0.38) at T1 and 4.58 (SD = 0.35) at T2, indicating consistently strong acceptance of the fortified bouillon cubes with minimal change over time. In the unadjusted model, the estimated mean difference was ($\beta = -0.01$; 95% CrI = $[-0.06, 0.04]$). In the adjusted model, the estimated mean difference was ($\beta = -0.01$; 95% CrI = $[-0.06, 0.04]$). The interaction between time point and group was also non-significant ($\beta = -0.01$, 95% CrI $[-0.09, 0.06]$), suggesting consistent acceptance scores across groups over time. No adverse events related to bouillon consumption were reported during the study period.

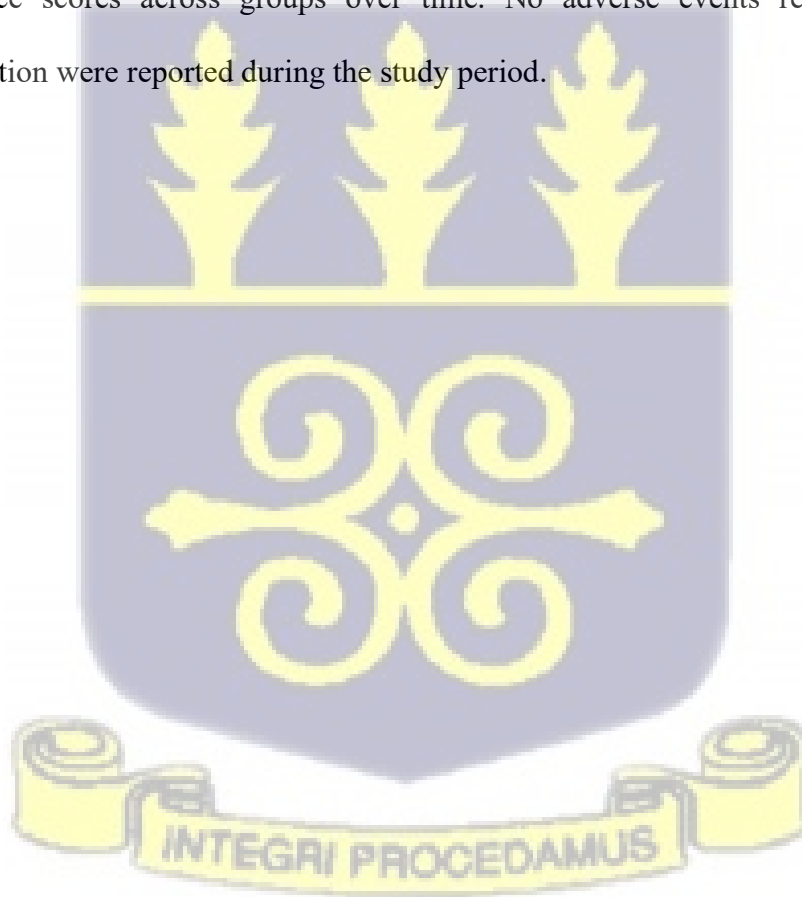


Table 6.5. Change in acceptance of study-supplied bouillon cubes among non-index household members between early (T1) and late (T2) intervention phases

Variables	Posterior Mean Estimate (β)	95% Credible Interval (CrI)	Raw Mean (Mean $\pm$ SD)
Unadjusted model for the acceptance			
Time point (T2 vs. T1)	-0.01	-0.06, 0.04	T1: 4.59 $\pm$ 0.38; T2: 4.58 $\pm$ 0.35
Random intercept			
SD (participant intercept)	0.04	0.00, 0.10	NA
Adjusted model			
Time point (T2 vs. T1)	-0.01	-0.06, 0.04	
Random intercept			
SD (participant intercept)	0.04	0.00, 0.09	NA

Note:

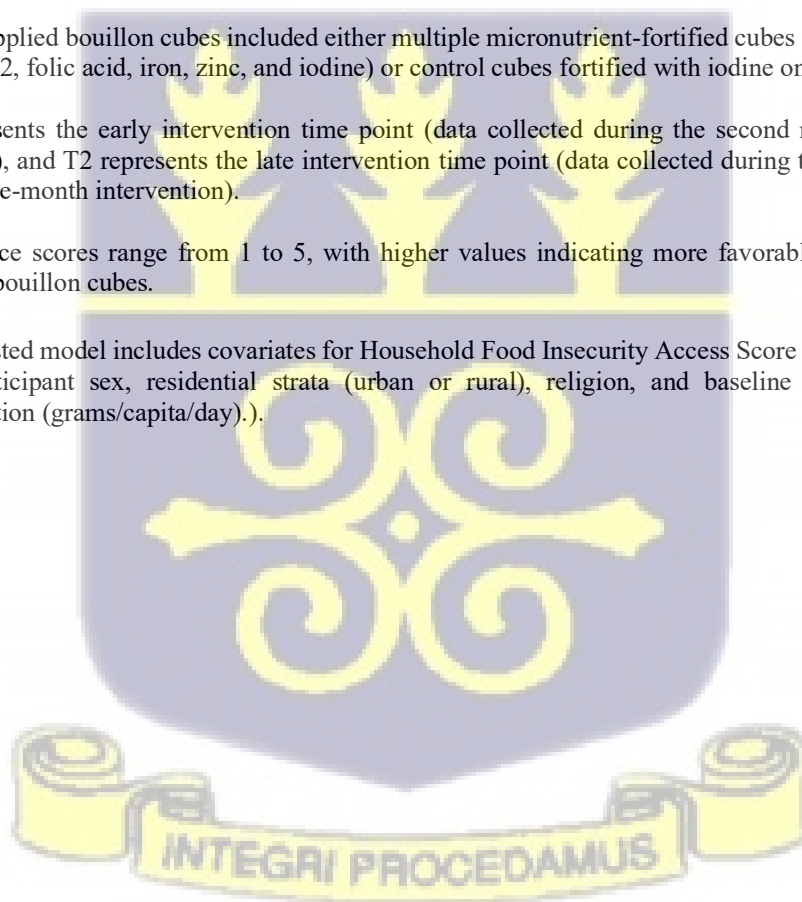
Posterior mean (β) values represent model-estimated mean differences in acceptance scores. Estimates were obtained using Bayesian linear mixed-effects models with random intercepts for participants. A 95% credible interval (CrI) that does not include 0 indicates statistical significance (*).

Study-supplied bouillon cubes included either multiple micronutrient-fortified cubes (containing vitamins A and B12, folic acid, iron, zinc, and iodine) or control cubes fortified with iodine only.

T1 represents the early intervention time point (data collected during the second month of household exposure), and T2 represents the late intervention time point (data collected during the final two months of the nine-month intervention).

Acceptance scores range from 1 to 5, with higher values indicating more favorable acceptance of the fortified bouillon cubes.

The adjusted model includes covariates for Household Food Insecurity Access Score (HFIAS), household size, participant sex, residential strata (urban or rural), religion, and baseline household bouillon consumption (grams/capita/day).



Individual- and household-level factors associated with the perception towards the study-supplied bouillon cubes

Table 6.6 presents the associations between individual- and household-level factors and perception scores of the study-supplied bouillon cubes among NIHM.

At the individual level, occupation was associated with differences in perception scores. Compared to farmers, formal employees had lower perception scores ($\beta = -0.48$; 95% CrI = $[-0.73, -0.22]$). No significant differences in perception scores were observed for homemakers ($\beta = -0.06$; 95% CrI = $[-0.26, 0.14]$) or small business owners ($\beta = -0.16$; 95% CrI = $[-0.33, 0.01]$). Compared to household heads, more positive perception of the fortified bouillon cubes was observed among wives ($\beta = 0.54$; 95% CrI = $[0.32, 0.76]$), sons/daughters ($\beta = 0.45$; 95% CrI = $[0.21, 0.69]$), siblings/in-laws ($\beta = 0.40$; 95% CrI = $[0.16, 0.64]$), and parents ($\beta = 0.31$; 95% CrI = $[0.07, 0.55]$). No significant associations were found by participant sex ($\beta = 0.04$; 95% CrI = $[-0.16, 0.24]$) or household cooking role. Compared to participants who never cooked, perception scores did not differ significantly for primary cooks ($\beta = 0.02$; 95% CrI = $[-0.17, 0.22]$) or secondary/occasional cooks ($\beta = 0.16$; 95% CrI = $[-0.01, 0.34]$).

Among household-level factors, urban residence was associated with higher perception scores compared to rural residence ($\beta = 0.09$; 95% CrI = $[0.00, 0.18]$). No significant associations were observed for district of residence ($\beta = -0.01$; 95% CrI = $[-0.14, 0.11]$), sex of household head ($\beta = 0.18$; 95% CrI = $[-0.03, 0.39]$), socio-economic index ($\beta = 0.01$; 95% CrI = $[-0.03, 0.06]$), or baseline household bouillon consumption per day ($\beta = -0.03$; 95% CrI = $[-0.07, 0.02]$). No significant difference in perception scores was found between study arms ($\beta = 0.08$; 95% CrI = $[-0.01, 0.16]$). Acceptance was not

significantly associated with perception scores when included as a covariate ($\beta = -0.11$; 95% CrI = $[-0.23, 0.01]$).

A positive time effect was observed, with perception scores at T2 exceeding those at T1 ($\beta = 1.11$; 95% CrI = $[0.93, 1.30]$). At T2, lower perception scores were observed among participants in Tolon compared to those in Kumbungu ($\beta = -0.23$; 95% CrI = $[-0.40, -0.06]$). Compared to farmers, participants identified as small business owners ($\beta = 0.24$; 95% CrI = $[0.02, 0.46]$) and formal employees ($\beta = 0.64$; 95% CrI = $[0.29, 0.99]$) had larger time-related differences in perception scores. No significant time-related difference was observed for homemakers ($\beta = 0.04$; 95% CrI = $[-0.23, 0.31]$).

Compared to household heads, lower perception scores at T2 were observed among wives ($\beta = -0.63$; 95% CrI = $[-0.87, -0.40]$), sons/daughters ($\beta = -0.54$; 95% CrI = $[-0.86, -0.22]$), parents ($\beta = -0.37$; 95% CrI = $[-0.70, -0.06]$), and siblings/in-laws ($\beta = -0.42$; 95% CrI = $[-0.71, -0.12]$). Participant-level variation was accounted for using a random intercept (SD = 0.04; 95% CrI = $[0.00, 0.12]$).

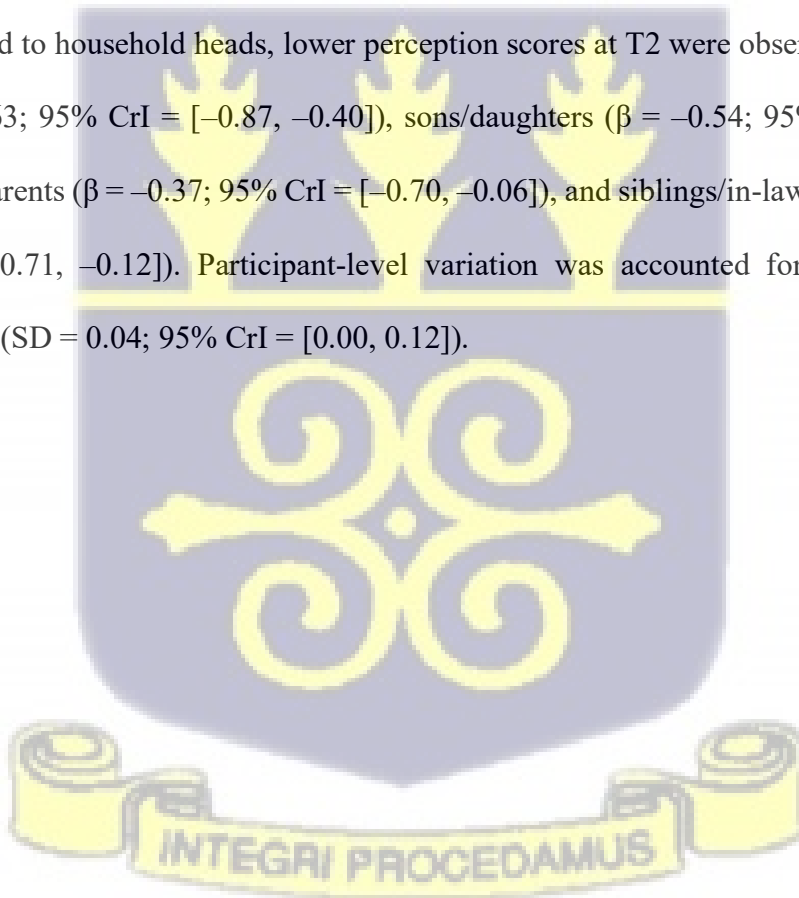


Table 6.6. Individual- and household factors associated with perception of study-supplied bouillon cubes among non-index household members at early (T1) and late (T2) intervention phases in the randomised trial

Variable	Categorical Levels	Posterior Mean Estimate (β)	95% Credible Interval (CrI)
Time point of Data Measurement	Early	<i>Ref.</i>	
	Late	1.11	0.93, 1.30*
Individual-level factors			
Occupation	Farming	<i>Ref.</i>	
	Homemaker	-0.06	-0.26, 0.14
	Small Business Owners	-0.16	-0.33, 0.01
	Formal Employees (Gov't/Private)	-0.48	-0.73, -0.22*
Participant Relationship with HH	HH	<i>Ref.</i>	
	Wives	0.54	0.32, 0.76*
	Sons/Daughters	0.45	0.21, 0.69*
	In-laws/Siblings	0.4	0.16, 0.64*
	Parents	0.31	0.07, 0.55*
Sex	Female	<i>Ref.</i>	
	Male	0.04	-0.16, 0.24
Household Cooking Role	Never Cooks	<i>Ref.</i>	
	Primary Cooks	0.02	-0.17, 0.22
	Secondary/Occasional Cooks	0.16	-0.01, 0.34
Household-level factors			
Strata	Rural	<i>Ref.</i>	
	Urban	0.09	0.00, 0.18*
District	Kumbungu	<i>Ref.</i>	
	Tolon	-0.01	-0.14, 0.11
Sex of HH	Female	<i>Ref.</i>	
	Male	0.18	-0.03, 0.39
Socio-economic Index		0.01	-0.03, 0.06
Household Bouillon Consumption (g/day)		-0.03	-0.07, 0.02
Study Arm	Group AA	<i>Ref.</i>	
	Group BB	0.08	-0.01, 0.16
Acceptance Composite Score		-0.11	-0.23, 0.01
Time point and interaction effect			
Interaction: Late $\times$ District	Kumbungu	<i>Ref.</i>	
	Tolon	-0.23	-0.40, -0.06*
Interaction: Late $\times$ Occupation	Farming	<i>Ref.</i>	
	Homemaker	0.04	-0.23, 0.31
	Small Business Owners	0.24	0.02, 0.46*

Interaction: Late × Relationship with HH	Formal Employees	0.64	0.29, 0.99*
	Household Head	Ref.	
	Wife	-0.63	-0.87, -0.40*
	Sons/Daughters	-0.54	-0.86, -0.22*
	Parents	-0.37	-0.70, -0.06*
	In-laws/Siblings	-0.42	-0.71, -0.12*
Random Effect (Participant-level)	SD (Intercept)	0.04	0.00, 0.12

Note:

Study-supplied bouillon cubes included either multiple micronutrient-fortified cubes (containing vitamins A and B12, folic acid, iron, zinc, and iodine) or control cubes fortified with iodine only.

A 95% credible interval (CrI) that does not include 0 indicates statistical significance (*).

The socio-economic index was derived from a composite household asset score.

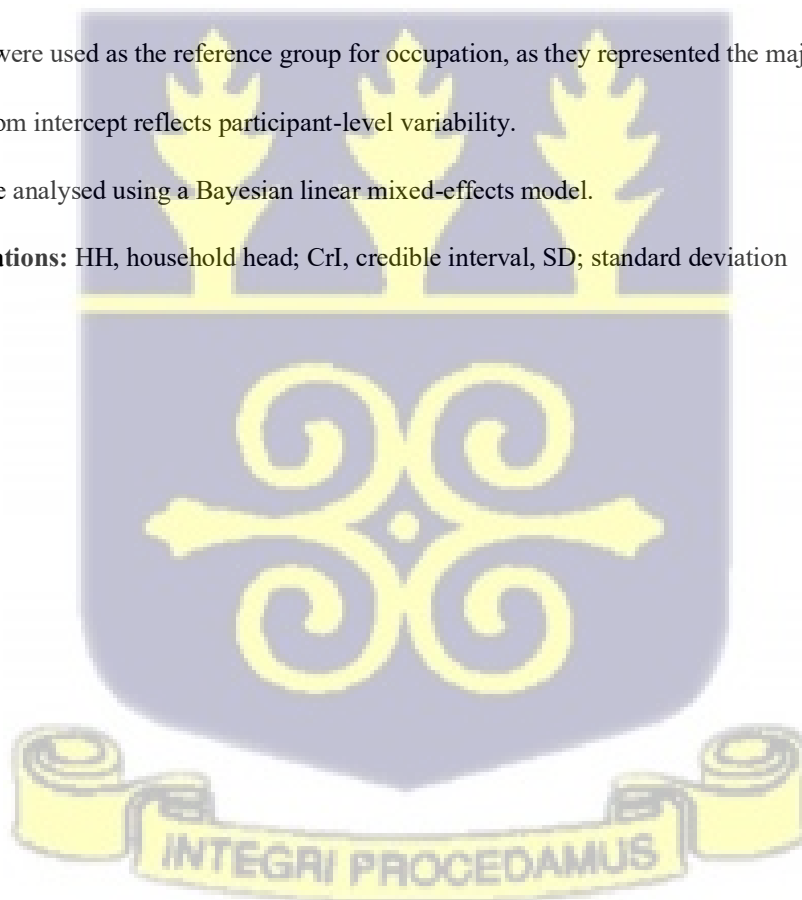
Household bouillon consumption was calculated as total grams used per day divided by household size, resulting in per capita daily intake (g/day).

Farmers were used as the reference group for occupation, as they represented the majority of participants.

The random intercept reflects participant-level variability.

Data were analysed using a Bayesian linear mixed-effects model.

Abbreviations: HH, household head; CrI, credible interval, SD; standard deviation



Individual- and household-level factors associated with the acceptance towards the study-supplied bouillon cubes

Table 6.7 presents the associations between individual- and household-level factors and acceptance scores of the study-supplied bouillon cubes among NIHM.

At the individual level, male participants had higher acceptance scores compared to female participants ($\beta = 0.05$; 95% CrI = [0.01, 0.09]). Occupation was associated with acceptance scores. Compared to farmers, small business owners had higher scores ($\beta = 0.06$; 95% CrI = [0.01, 0.11]), while no significant differences were observed for homemakers ($\beta = 0.05$; 95% CrI = [-0.01, 0.11]) or formal employees ($\beta = 0.05$; 95% CrI = [-0.02, 0.13]). Religion was not significantly associated with acceptance scores, with participants identifying as Christian or Traditionalist showing no significant difference from Muslims ($\beta = 0.12$; 95% CrI = [-0.02, 0.27]).

Among household-level factors, urban residence was associated with lower acceptance scores compared to rural residence ($\beta = -0.08$; 95% CrI = [-0.12, -0.04]). Compared to food-secure households, mildly food-insecure households had lower acceptance scores ($\beta = -0.07$; 95% CrI = [-0.12, -0.01]), while severely food-insecure households had higher acceptance scores ($\beta = 0.12$; 95% CrI = [0.05, 0.19]). No significant difference was observed for moderately food-insecure households ($\beta = -0.01$; 95% CrI = [-0.05, 0.04]).

Household bouillon consumption, measured in grams per capita per day, was negatively associated with acceptance scores ($\beta = -0.03$; 95% CrI = [-0.04, -0.01]), and the socio-economic index was positively associated with acceptance ($\beta = 0.03$; 95% CrI = [0.01, 0.05]). No significant difference in acceptance scores was observed between participants in Group BB and those in Group AA ($\beta = 0.04$; 95% CrI = [0.00, 0.08]).

No significant difference in acceptance scores was observed between the intervention time points ($\beta = -0.01$; 95% CrI = $[-0.05, 0.02]$). Participant-level variability was accounted for using a random intercept (SD = 0.04; 95% CrI = $[0.00, 0.09]$).



Table 6.7. Individual- and household factors associated with acceptance of study-supplied bouillon cubes among non-index household members at early (T1) and late (T2) intervention phases in the randomised trial

Variable	Categorical levels	Estimate (β)	95% Credible Interval (CrI)
Time point of Data Measurement	Early	<i>Ref.</i>	
	Late	-0.01	-0.05, 0.02
Sex	Female	<i>Ref.</i>	
	Male	0.05	0.01, 0.09*
Occupation	Farming	<i>Ref.</i>	
	Homemaker	0.05	-0.01, 0.11
	Small Business Owners	0.06	0.01, 0.11*
	Formal Employees	0.05	-0.02, 0.13
Religion	Islam	<i>Ref.</i>	
	Christianity/Traditionist	0.12	-0.02, 0.27
Strata	Rural	<i>Ref.</i>	
	Urban	-0.08	-0.12, -0.04*
Household Food Insecurity	Food Secure	<i>Ref.</i>	
	Mildly Food Insecure	-0.07	-0.12, -0.01*
	Moderately Food Insecure	-0.01	-0.05, 0.04
	Severely Food Insecure	0.12	0.05, 0.19*
Household Bouillon Consumption (g/day)		-0.03	-0.04, -0.01*
Socio-economic Index		0.03	0.01, 0.05*
Study Arm	Group AA	<i>Ref.</i>	
	Group BB	0.04	0.00, 0.08
Random Effect (Participant-level)	Intercept (SD)	0.04	0.00, 0.09

Note:

Study-supplied bouillon cubes included either multiple micronutrient-fortified cubes (containing vitamins A and B12, folic acid, iron, zinc, and iodine) or control cubes fortified with iodine only.

A 95% credible interval (CrI) that does not include 0 indicates statistical significance (*).

The socio-economic index was derived from a composite household asset score.

Household bouillon consumption was calculated as total grams used per day divided by household size, resulting in per capita daily intake (g/day).

Farmers were used as the reference group for occupation, as they represented the majority of participants.

The random intercept reflects participant-level variability.

Data were analysed using a Bayesian linear mixed-effects model.

Abbreviations: HH, household head; CrI, credible interval.

Qualitative Results

Drivers and barriers to the acceptance of the intervention bouillon cubes were explored through FGDs with male ($n = 74$) and female ($n = 83$) participants. Participant characteristics are summarized in Table 6.8. Thematic analysis identified five key themes: (1) health and well-being, (2) sensory and practical experiences, (3) cultural compatibility and cooking habits, (4) economic benefits influencing acceptance, and (5) perceived challenges and barriers to acceptance. Themes and illustrative quotations are provided in **Supplemental material 1 in the appendix.**

Theme 1: *Health and well-being*

Participants reported noticeable reductions in minor ailments such as stomach pains, headaches, fever, and diarrhoea, especially among children. Female participants often attributed these improvements to the study-supplied bouillon cubes, citing fewer hospital visits and improved blood levels in their children.

One participant shared, “Since we started using the study-supplied bouillon cubes, I’ve noticed my children fall sick less often. Their energy levels have improved significantly” (Female participant, Household head’s Wife, Homemaker).

Another highlighted benefits for older adults: “The study cubes have been a blessing for my family. My elderly parents feel more energetic and less fatigued” (Male participant, Household head, Small Business Owner).

Theme 2: *Sensory and practical experiences*

Participants reported favourable sensory impressions of the study-supplied bouillon cubes, noting their balanced taste, mild saltiness, and compatibility with traditional dishes. The cubes were described as dissolving quickly and being easy to incorporate into routine cooking. Some participants compared the study cubes to commercial alternatives, observing that the study cubes were less sweet and more suited to local tastes.

One participant remarked, *“The taste of the study cubes is perfect for our traditional soups and stews. It's not too salty or overpowering”* (Female, Landlord’s Wife, SHS).

Another participant emphasised the cultural fit, stating, *“We love the flavour of the study cubes. They make our meals delicious as the way we want the food to taste”* (Male, Landlord, No Formal Education).

Theme 3: *Cultural compatibility and cooking habits*

Participants emphasised that the study-supplied bouillon cubes aligned well with traditional cooking practices and complemented a wide variety of local dishes. The cubes were perceived as fitting seamlessly into everyday household meal preparation without altering familiar tastes.

As one participant explained, *“The study cubes fit perfectly with our traditional recipes. They don't change the original taste of our dishes”* (Female, Landlord’s Wife, No Formal Education).

Theme 4: *Economic benefits influencing acceptance*

Participants highlighted the financial advantages of using the study-supplied bouillon cubes, noting reduced reliance on other condiments and associated household cost savings. These benefits were frequently emphasised by male participants, who linked the cubes to decreased spending on both seasonings and healthcare.

One male participant shared, *“Switching to the study cubes has been great for our budget. They're free and give us blood as we do not fall sick frequently any longer”* (Male, Landlord, No Formal Education).

Similarly, a female participant remarked, *“We have cut down on healthcare costs since using the study-supplied cubes. They're an economical choice for our family because I do not get blood shortage anymore”* (Female, Landlord's Wife, SHS)..

Theme 5: *Perceived challenges and barriers to acceptance*

While overall acceptance was high, some participants reported minor concerns that influenced their initial perceptions of the study-supplied bouillon cubes. Changes in food colour, particularly the darkening of soups prepared with green leafy vegetables, were commonly noted. A few participants expressed concerns about long-term health effects, including fears related to male infertility.

One participant shared, *“Initially, I thought the study cube will serve as family planning and would reduce our sexual performing ability but as time goes on, I realized I could perform better”* (Male, Landlord, No Formal Education).

Another remarked, *“Sometimes the intervention cubes change the colour of our soups to dark, especially the green leafy ones. It's not a major issue, but it's noticeable”* (Female, Landlord's Wife, JHS).

Overall drivers of acceptance and usage

Across demographic groups, participants reported using the study bouillon cubes and expressed a preference for them over commercial alternatives. Reported drivers of use included perceived health benefits, convenience, sensory appeal, and financial considerations. The cubes were reportedly used in a wide variety of meals.

Sentiment Analysis

Participants' narratives reflected predominantly positive sentiments towards the study-supplied bouillon cubes, with trust and joy being the most frequently expressed emotions. Confidence in the cubes' health benefits and quality was commonly reported.

For example, one participant noted, *“We know the study cubes have improved our health and well-being, which makes us believe it is good thing”* (Female, Landlord's Wife, No Formal Education).

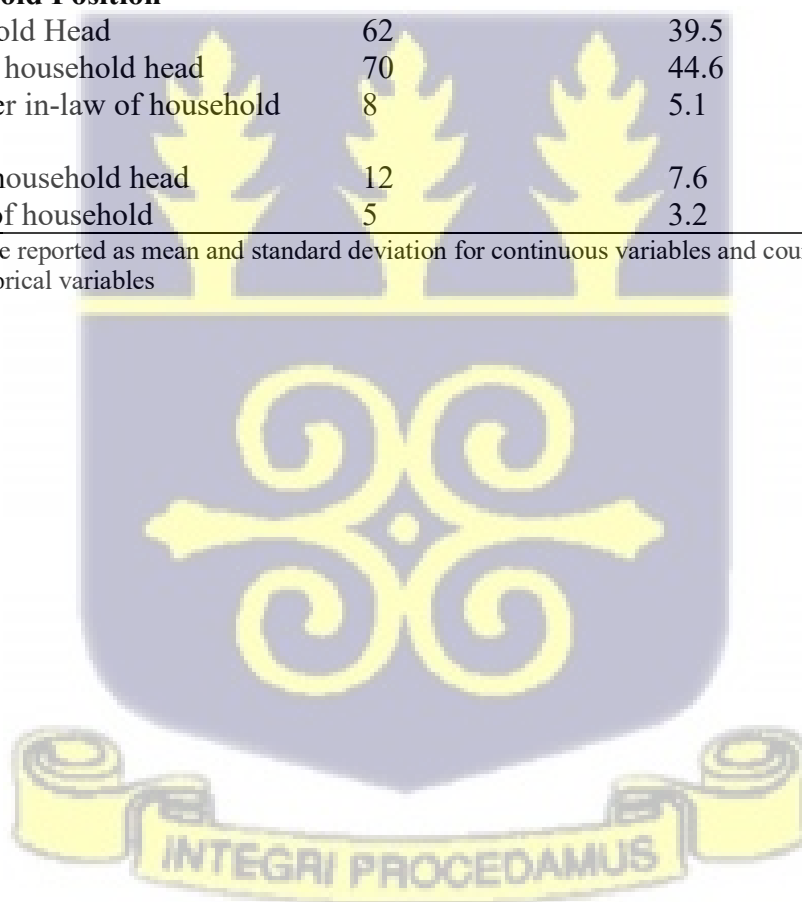
Negative sentiments were relatively rare and centred on uncertainty about potential long-term effects, as illustrated by the comment, *“I'm just cautious about how the fortified cubes might affect us in the long run”* (Male, Landlord, No Formal Education).

Sentiment trends disaggregated by sex are shown in **Figure 2**.

Table 6. 8. Background characteristics of Focus Group Discussion (total $n = 157$)

Characteristics	n	Percentage (%)
Age, y	157	43.8 $\pm$ 12.3 years
Sex		
Male	74	47.1
Female	83	52.9
Educational level		
No formal education	106	67.5
Primary	15	9.6
JHS	14	8.9
SHS & above	22	14.0
Occupation		
Farming/Agricultural	85	54.1
Petty traders	50	31.8
Skilled labour	20	12.7
Government/private worker	2	1.3
Household Position		
Household Head	62	39.5
Wife of household head	70	44.6
Daughter in-law of household head	8	5.1
Son of household head	12	7.6
Parent of household	5	3.2

Values are reported as mean and standard deviation for continuous variables and count and proportion for categorical variables



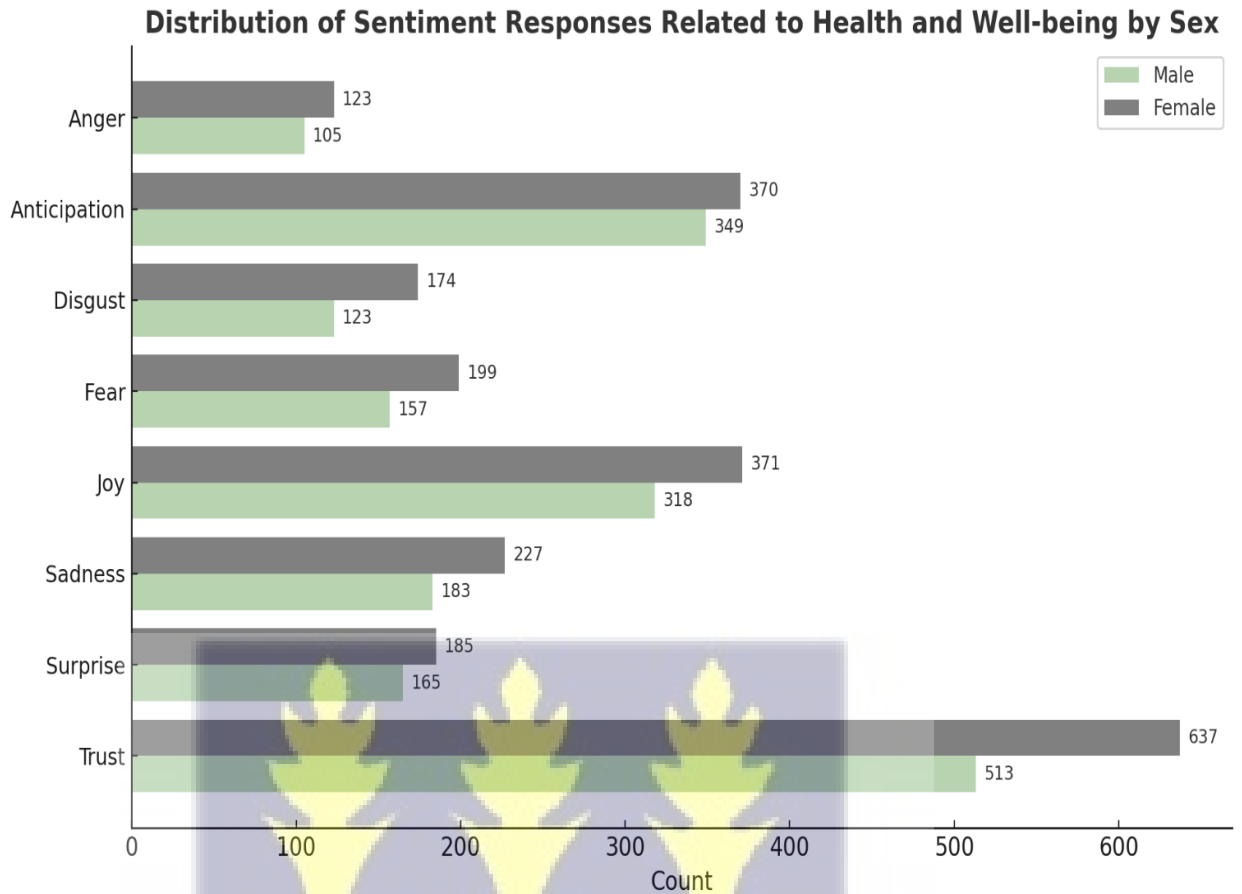


Fig. 2. Distribution of sentiment responses related to health and well-being among male and female participants in focus group discussions (FGDs)

Bars represent the number of times each sentiment was expressed in FGD transcripts, based on automated sentiment analysis using the NRC sentiment lexicon. Overall, positive sentiments were more common than negative sentiments. *Trust* was the most frequently expressed sentiment, while *joy* and *anticipation* were also prominent. *Joy* denotes present-oriented happiness and satisfaction, whereas *anticipation* reflects future-oriented optimism. Negative sentiments, particularly sadness, fear, and disgust, were also substantially represented, highlighting participants' concerns about health-related challenges and unmet needs.

Discussion

This study aimed to assess longitudinal changes in perception and acceptance of fortified bouillon cubes among non-index household members (NIHMs) in Northern Ghana and to examine individual- and household-level factors influencing these outcomes. Perception improved significantly over the nine-month intervention period, while acceptance remained consistently high. These patterns were similar across intervention arms, indicating widespread acceptability and increasing favourability over time.

Qualitative findings provided context, identifying perceived health improvements, favourable taste, cultural compatibility, and cost savings as major facilitators of use, while infertility myths and concerns about colour change were key barriers. These results suggest that fortified bouillon cubes are not only culturally compatible but also increasingly trusted when used regularly in household cooking.

Furthermore, subgroup analyses showed that increases in perception were greatest among household heads, formal employees, and small business owners. These groups had initially reported lower scores, which suggests that experiential learning contributed to improved attitudes over time. Acceptance varied modestly across subgroups, with higher levels observed among men, small business owners, and severely food-insecure households, but lower levels among urban households and those with higher baseline household bouillon consumption. These patterns highlight the influence of socio-economic context and prior exposure on acceptance.

A key strength of this study is its longitudinal mixed-methods design. By combining repeated quantitative measures within a double-blind randomised controlled trial with mid-intervention qualitative enquiry, it offers a well-grounded understanding of

changes in perception and acceptance throughout the study period. To our knowledge, this is the first study to assess changes in perception and acceptance of fortified bouillon cubes among NIHMs within an RCT context. This approach enabled a rigorous evaluation of temporal shifts in consumer responses while capturing contextual and cultural influences (Creswell & Clark, 2017; Guetterman & Fetters, 2018; Plano Clark, 2017). Measurement validity was strengthened through the development of composite scores EFA and CFA, with high construct reliability and adequate factor loadings (Brown, 2015; Hair Jr et al., 2020). The application of Bayesian linear mixed-effects models further enhanced the analysis by estimating time-related effects and covariate associations while accounting for individual-level variability and uncertainty (Chen et al., 2022; van de Schoot et al., 2021).

However, some limitations must be acknowledged. First, analyses were restricted to complete cases ($n = 676$); however, comparisons of baseline characteristics between completers and non-completers showed no statistically significant differences, suggesting minimal attrition bias. Second, reliance on self-reported data may have introduced recall or social desirability bias (Bradburn et al., 1987; Durmaz et al., 2020), although this was mitigated by triangulation with FGDs. Third, the study was conducted in a predominantly Dagomba and Islamic setting, with cubes provided at no cost, which may limit generalisability to other cultural or market-based contexts. Nonetheless, bouillon consumption is widespread across Ghana and much of West Africa (Engle-Stone et al., 2021; Garcia-Casal et al., 2016; Matthias et al., 2022), suggesting that these findings are likely relevant for regional nutrition programming and fortification policies. Results may differ in areas with lower bouillon use, where fortified cubes are purchased, or if alternative micronutrient formulations are used. Finally, the absence of biochemical data limits the

ability to verify perceived health improvements or consumption frequency. Though biomarker analyses among index participants are planned and will be reported separately.

Findings align with behavioural theories such as the Theory of Planned Behaviour (TPB) and the Health Belief Model (HBM), which posit that repeated exposure reinforces attitudes and social norms (Ajzen, 1991; Rosenstock, 1974). The observed increase in perception over time, alongside consistently high acceptance, mirrors results from prior studies in Ghana and Nigeria, where perceived health benefits and visible improvements in children's well-being fostered trust in fortified products (Adams et al., 2018; Adu-Afarwuah et al., 2008; GAIN, 2024; Kyei-Arthur et al., 2024; Wessells et al., 2024).

Although participants frequently reported health improvements, perception and acceptance scores did not differ significantly between fortified and control groups. This likely reflects both strong blinding of cube allocation and the fact that micronutrient fortification did not adversely affect sensory characteristics. Concerns are often raised that fortification may alter taste, aroma, or colour (Archer et al., 2022), yet peer-reviewed study in Ghana have found no significant differences in sensory ratings between fortified and control cubes (Wessells et al., 2024), aligning with our findings. This external evidence strengthens our finding that fortification did not constitute a barrier to acceptance in this context. While some respondents reported differences compared with commercial cubes, these likely reflected formulation or flavouring variations rather than the micronutrient premix. Together, these results indicate that micronutrient fortification can be implemented without compromising sensory appeal, an important consideration given that sensory properties, cultural relevance, and affordability are well-recognized drivers of fortified food acceptance (Creed-Kanashiro et al., 2016; Field et al., 2017). These themes were

evident in both quantitative and qualitative findings, with participants citing flavours enhancement, ease of use, and economic advantages as reasons for continued use.

Given bouillon's ubiquity in daily cooking, it remains a practical and familiar medium for micronutrient delivery. However, the study's results suggest the need to refine existing behavioral models. Attributes such as taste and aroma, though not central to traditional TPB or HBM constructs, clearly shaped perceptions and decisions. Likewise, the free provision of cubes may have enhanced perceived behavioral control. These factors warrant further consideration in future adaptations of behavioral models in nutrition research.

Sociodemographic differences highlight the influence of household roles and responsibilities. Higher perception among wives and greater acceptance among farmers likely reflect their central role in meal preparation and food planning. NIHMs, though not enrolled as index participants, were often the primary cooks or food decision-makers, meaning their attitudes likely shaped intervention adherence. High acceptance among key members likely supported regular cube use, whereas limited acceptance among influential members may have constrained reach (Gillespie et al., 2015; Kavle & Landry, 2018). Future studies should explicitly measure intra-household decision-making to better understand these behavioral pathways.

Bouillon cubes are a contributor to dietary sodium intake in many low- and middle-income countries, including Ghana, where excessive sodium consumption has been linked to elevated blood pressure and other non-communicable disease risks (Archer et al., 2022; Das et al., 2019). Although bouillon is also a means for micronutrient fortification, concerns about sodium content and food processing may influence attitudes, as observed

in pilot focus groups where participants mentioned salt intake and hypertension (Davis et al., 2024).

The persistently high acceptance scores, despite increases in perception, may indicate a ceiling effect. Acceptance may have been near saturation at early intervention, limiting detectable increases by late intervention (Liu & Wang, 2021; Šimkovic & Träuble, 2019). This raises questions about the sensitivity of current tools to detect marginal changes and underscores the need for more refined instruments in future studies. Moreover, this ceiling effect may have masked the impact of specific drivers, such as promotional messages or packaging innovations, that could have otherwise further increased acceptance over time.

Policy implications are significant. Fortified bouillon cubes demonstrate strong acceptability, cultural relevance, and affordability, key ingredients for sustainable scale-up. Unlike other fortification vehicles such as maize or rice, which have sometimes faced resistance due to taste or preparation concerns (Baker et al., 2022; Fiorentini et al., 2020; Kuong et al., 2019). However, bouillon cubes are already deeply embedded in daily cooking practices, making them a practical fortification platform. National strategies should leverage this by introducing enabling mechanisms such as subsidies, tax incentives for producers, and public–private partnerships (Bhutta et al., 2013; Keats et al., 2019; WHO, 2020). Scale-up efforts should include sodium monitoring and public messaging to address NCD risks. Future research should incorporate objective biomarkers (e.g., haemoglobin, iodine), investigate potential ceiling effects, and refine acceptability measurement tools. Replication in diverse socio-cultural and market-based contexts will further inform generalisability and optimize public health impact.

In conclusion, fortified bouillon cubes were highly accepted and well-integrated into household cooking practices. Perception improved over time, especially among groups initially less favourable. With appropriate monitoring and context-specific implementation, bouillon cube fortification offers a promising, culturally compatible strategy for addressing micronutrient deficiencies in Ghana and across West Africa. These findings provide evidence to inform nutrition programming and fortification strategies across West Africa, where bouillon cube use is similarly widespread.



REFERENCE

- Abizari, A.-R., Azupogo, F., Nagasu, M., Creemers, N., & Brouwer, I. D. (2017). Seasonality affects dietary diversity of school-age children in northern Ghana. *PloS one*, 12(8), e0183206.
- Abizari, A.-R., Dold, S., Kupka, R., & Zimmermann, M. B. (2017). More than two-thirds of dietary iodine in children in northern Ghana is obtained from bouillon cubes containing iodized salt. *Public Health Nutrition*, 20(6), 1107-1113.
- Adu-Afarwuah, S., Lartey, A., Brown, K. H., Zlotkin, S., Briend, A., & Dewey, K. G. (2008). Home fortification of complementary foods with micronutrient supplements is well accepted and has positive effects on infant iron status in Ghana. *The American journal of clinical nutrition*, 87(4), 929-938.
- Ajzen, I. (1991). The theory of planned behaviour. *Organizational behaviour and human decision processes*, 50(2), 179-211.
- Ajzen, I., Lange, P., Kruglanski, A., & Higgins, E. (2012). Handbook of theories of social psychology. *Chapter*, 21, 438-460.
- Anuar, H., Shah, S., Gafor, H., Mahmood, M., & Ghazi, H. F. (2020). Usage of Health Belief Model (HBM) in health behaviour: A systematic review. *Malaysian Journal of Medicine and Health Sciences*, 16(11), 2636-9346.
- Bailey, R. L., West Jr, K. P., & Black, R. E. (2015). The epidemiology of global micronutrient deficiencies. *Annals of nutrition and metabolism*, 66(Suppl. 2), 22-33.
- Baker, M. T., Lu, P., Parrella, J. A., & Leggette, H. R. (2022). Consumer Acceptance toward Functional Foods: A Scoping Review. *Int J Environ Res Public Health*, 19(3). <https://doi.org/10.3390/ijerph19031217>
- Chauhan, U., & Shah, A. (2021). Topic modeling using latent Dirichlet allocation: A survey. *ACM Computing Surveys (CSUR)*, 54(7), 1-35.
- Chen, D.-G., Lio, Y., & Wilson, J. R. (2022). Bayesian Approach for Joint Modeling Longitudinal Data and Survival Data Simultaneously in Public Health Studies. In Y. Lio, D.-G. Chen, H. K. T. Ng, & T.-R. Tsai (Eds.), *Bayesian Inference and Computation in Reliability and Survival Analysis* (pp. 343-355). Springer International Publishing. https://doi.org/10.1007/978-3-030-88658-5_16
- Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2024). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. *Asia Pacific Journal of Management*, 41(2), 745-783.
- Christian, A. K., Marquis, G. S., Colecraft, E. K., Lartey, A., Sakyi-Dawson, O., Ahunu, B. K., & Butler, L. M. (2016). Caregivers' nutrition knowledge and attitudes are associated with household food diversity and children's animal source food intake across different agro-ecological zones in Ghana. *British Journal of Nutrition*, 115(2), 351-360.
- Coates, J., Swindale, A., & Bilinsky, P. (2007). Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide: version 3.

- Creed-Kanashiro, H., Bartolini, R., Abad, M., & Arevalo, V. (2016). Promoting multi-micronutrient powders (MNP) in Peru: Acceptance by caregivers and role of health personnel. *Maternal & child nutrition*, 12(1), 152-163.
- Eilander, A., Verbakel, M. R., & Dötsch-Klerk, M. (2023). The Potential of Condiments, Seasonings, and Bouillon Cubes to Deliver Essential Micronutrients in Asia: Scenario Analyses of Iodine and Iron Fortification. *Nutrients*, 15(3), 616.
- Engle-Stone, R., Kumordzie, S. M., Luo, H., Wessells, K. R., Adu-Afarwuah, S., Njebayi, A., Teta, I., Régis, Y.-L., Gyimah, E., & Vosti, S. A. (2024). The potential for bouillon fortification to reduce dietary micronutrient inadequacy: Modeling analyses using national survey data from Cameroon, Ghana, and Haiti. *Current Developments in Nutrition*, 104485.
- Erzse, A., Goldstein, S., Tugendhaft, A., Norris, S. A., Barker, M., & Hofman, K. J. (2021). The roles of men and women in maternal and child nutrition in urban South Africa: A qualitative secondary analysis. *Matern Child Nutr*, 17(3), e13161. <https://doi.org/10.1111/mcn.13161>
- Fiorentini, M., Kinchla, A. J., & Nolden, A. A. (2020). Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. *Foods*, 9(9), 1334. <https://www.mdpi.com/2304-8158/9/9/1334>
- Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behaviour: The reasoned action approach*. Psychology press.
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 18(1), 39-50.
- GAIN. (2023a). *GAIN, Mighty Nutrients Coalition Policy Brief: Preventing Micronutrient Deficiencies Worldwide Advocacy Actions to Support WHO's World Health Assembly Resolution on Food Fortification*. Retrieved 10/7/2024 from <https://www.gainhealth.org/sites/default/files/publications/documents/Mighty-Nutrients-Coalition-Policy-Brief-Preventing-Micronutrient-Deficiencies-Worldwide.pdf#:~:text=URL%3A%20https%3A%2F%2Fwww.gainhealth.org%2Fsites%2Fdefault%2Ffiles%2Fpublications%2Fdocuments%2FMighty>
- GAIN. (2023b). *Regulatory monitoring of national food fortification programs: A policy guidance document*. <https://www.gainhealth.org/sites/default/files/publications/documents/regulatory-monitoring-policy-guidance-doc-2018.pdf>
- GAIN. (2024). *Large-Scale Food Fortification*. Retrieved 5/7/2024 from <https://www.gainhealth.org/impact/programmes/food-fortification/large-scale-food-fortification>
- Gelman, A., Vehtari, A., Simpson, D., Margossian, C. C., Carpenter, B., Yao, Y., Kennedy, L., Gabry, J., Bürkner, P.-C., & Modrák, M. (2020). Bayesian workflow. *arXiv preprint arXiv:2011.01808*.
- Goretzko, D., Siemund, K., & Sterner, P. (2024). Evaluating model fit of measurement models in confirmatory factor analysis. *Educational and Psychological Measurement*, 84(1), 123-144.
- Gosdin, L., Sharma, A. J., Tripp, K., Amoahful, E. F., Mahama, A. B., Selenje, L., Jefferds, M. E., Martorell, R., Ramakrishnan, U., & Addo, O. Y. (2021). A school-based weekly iron and folic acid supplementation program effectively reduces anemia in

- a prospective cohort of Ghanaian adolescent girls. *The Journal of nutrition*, 151(6), 1646-1655.
- Hair Jr, J. F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, 109, 101-110.
- Hatem, G., Zeidan, J., Goossens, M., & Moreira, C. (2022). Normality testing methods and the importance of skewness and kurtosis in statistical analysis. *BAU Journal-Science and Technology*, 3(2), 7.
- Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288.
- Jongen, C., McCalman, J., & Bainbridge, R. (2018). Health workforce cultural competency interventions: a systematic scoping review. *BMC Health Serv Res*, 18(1), 232. <https://doi.org/10.1186/s12913-018-3001-5>
- Katenga-Kaunda, L. Z., Iversen, P. O., Kamudoni, P. R., Holmboe-Ottesen, G., & Fjeld, H. E. (2022). Food-based nutrition counselling and education intervention for improved diets of pregnant women in rural Malawi: a qualitative study of factors influencing dietary behaviour change. *Public Health Nutrition*, 25(9), 2436-2447.
- Keats, E. C., Akseer, N., Thurairajah, P., Cousens, S., & Bhutta, Z. A. (2022). Multiple-micronutrient supplementation in pregnant adolescents in low- and middle-income countries: a systematic review and a meta-analysis of individual participant data. *Nutr Rev*, 80(2), 141-156. <https://doi.org/10.1093/nutrit/nuab004>
- Keats, E. C., Neufeld, L. M., Garrett, G. S., Mbuya, M. N., & Bhutta, Z. A. (2019). Improved micronutrient status and health outcomes in low-and middle-income countries following large-scale fortification: evidence from a systematic review and meta-analysis. *The American journal of clinical nutrition*, 109(6), 1696-1708.
- Kim, N. (2020). Omnibus tests for multivariate normality based on Mardia's skewness and kurtosis using normalizing transformation. *Communications for Statistical Applications and Methods*, 27(5), 501-510.
- Kumordzie, S., Davis, J., Adams, K., Tan, X., Adu-Afarwuah, S., Wessells, K. R., Arnold, C., Becher, E., Haskell, M., & Vosti, S. (2021). Understanding Patterns and Drivers of Bouillon Use in Northern Ghana to Inform Fortification Planning. *Current Developments in Nutrition*, 5, 5140655.
- Kyei-Arthur, F., Aballo, J., Mahama, A. B., & Adu-Afarwuah, S. (2024). Infant and young child feeding practices among mothers in the pilot Micronutrient Powder Initiative in four geographically and ethnically diverse districts in Ghana. *PloS one*, 19(8), e0307961.
- Kyei-Arthur, F., Situma, R., Aballo, J., Mahama, A. B., Selenje, L., Amoafu, E., & Adu-Afarwuah, S. (2020). Lessons learned from implementing the pilot Micronutrient Powder Initiative in four districts in Ghana. *BMC nutrition*, 6, 1-13.
- Kyriazos, T. A. (2018). Applied psychometrics: sample size and sample power considerations in factor analysis (EFA, CFA) and SEM in general. *Psychology*, 9(08), 2207.
- Lamstein, S., Koniz-Booher, P., Beall, K., Aakesson, A., & Anson, M. (2014). SBCC pathways for improved maternal, infant, and young child nutrition practices. In: SPRING. <https://www.spring-nutrition.org/sites/default/files/publications....>

- Latkin, C. A., Edwards, C., Davey-Rothwell, M. A., & Tobin, K. E. (2017). The relationship between social desirability bias and self-reports of health, substance use, and social network factors among urban substance users in Baltimore, Maryland. *Addict Behav*, 73, 133-136. <https://doi.org/10.1016/j.addbeh.2017.05.005>
- Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: guided by information power. *Qualitative health research*, 26(13), 1753-1760.
- Mannar, M. V., & Hurrell, R. F. (2018). Food fortification: past experience, current status, and potential for globalization. In *Food fortification in a globalized world* (pp. 3-11). Elsevier.
- McNeish, D., & Wolf, M. G. (2023). Dynamic fit index cutoffs for confirmatory factor analysis models. *Psychological methods*, 28(1), 61.
- Miassi, Y. E., Dossa, F. K., Zannou, O., Akdemir, Ş., Koca, I., Galanakis, C. M., & Alamri, A. S. (2022). Socio-cultural and economic factors affecting the choice of food diet in West Africa: a two-stage Heckman approach. *Discover Food*, 2(1), 16.
- Moretti, D., Hurrell, R. F., & Cercamondi, C. I. (2018). Bouillon cubes. In *Food fortification in a globalized world* (pp. 159-165). Elsevier.
- Nandwani, P., & Verma, R. (2021). A review on sentiment analysis and emotion detection from text. *Social network analysis and mining*, 11(1), 81.
- Nyumuah, R. O., Hoang, T. C., Amoah, E. F., Agble, R., Meyer, M., Wirth, J. P., Locatelli-Rossi, L., & Panagides, D. (2012). Implementing large-scale food fortification in Ghana: lessons learned. *Food Nutr Bull*, 33(4 Suppl), S293-300. <https://doi.org/10.1177/15648265120334s305>
- Olson, R., Gavin-Smith, B., Ferraboschi, C., & Kraemer, K. (2021). Food Fortification: The Advantages, Disadvantages and Lessons from Sight and Life Programs. *Nutrients*, 13(4). <https://doi.org/10.3390/nu13041118>
- Osendarp, S. J. M., Martinez, H., Garrett, G. S., Neufeld, L. M., De-Regil, L. M., Vossenaar, M., & Darnton-Hill, I. (2018). Large-Scale Food Fortification and Biofortification in Low- and Middle-Income Countries: A Review of Programs, Trends, Challenges, and Evidence Gaps. *Food Nutr Bull*, 39(2), 315-331. <https://doi.org/10.1177/0379572118774229>
- Ozolins, U., Hale, S., Cheng, X., Hyatt, A., & Schofield, P. (2020). Translation and back-translation methodology in health research—a critique. *Expert review of pharmacoeconomics & outcomes research*, 20(1), 69-77.
- Petry, N., Wirth, J. P., Adu-Afarwuah, S., Wegmuller, R., Woodruff, B. A., Tanumihardjo, S. A., Bentil, H., Donkor, W. E. S., Williams, T. N., Shahab-Ferdows, S., Selenje, L., Mahama, A., Steiner-Asiedu, M., & Rohner, F. (2021). Risk factors for anaemia among Ghanaian women and children vary by population group and climate zone. *Matern Child Nutr*, 17(2), e13076. <https://doi.org/10.1111/mcn.13076>
- Rosenstock, I. M. (1974). Historical origins of the health belief model. *Health education monographs*, 2(4), 328-335.
- Ross-Hellauer, T., Deppe, A., & Schmidt, B. (2017). Survey on open peer review: Attitudes and experience amongst editors, authors and reviewers. *PloS one*, 12(12), e0189311. <https://doi.org/10.1371/journal.pone.0189311>

- Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American journal of Applied Mathematics and statistics*, 9(1), 4-11.
- Stevens, G. A., Beal, T., Mbuya, M. N., Luo, H., Neufeld, L. M., Addo, O. Y., Adu-Afarwuah, S., Alayón, S., Bhutta, Z., & Brown, K. H. (2022). Micronutrient deficiencies among pre-school-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys. *The Lancet Global Health*, 10(11), e1590-e1599.
- Storz, M. A., Beckschulte, K., Brommer, M., & Lombardo, M. (2022). Current Sex Distribution of Cooking and Food Shopping Responsibilities in the United States: A Cross-Sectional Study. *Foods*, 11(18). <https://doi.org/10.3390/foods11182840>
- Thériault, R., Ben-Shachar, M. S., Patil, I., Lüdecke, D., Wiernik, B. M., & Makowski, D. (2024). Check your outliers! An introduction to identifying statistical outliers in R with easystats. *Behaviour research methods*, 56(4), 4162-4172.
- Thompson, L., Becher, E., Adams, K. P., Haile, D., Walker, N., Tong, H., Vosti, S. A., & Engle-Stone, R. (2024). Modeled impacts of bouillon fortification with micronutrients on child mortality in Senegal, Burkina Faso, and Nigeria. *Annals of the new York Academy of Sciences*.
- Truong, M., Paradies, Y., & Priest, N. (2014). Interventions to improve cultural competency in healthcare: a systematic review of reviews. *BMC Health Services Research*, 14(1), 99. <https://doi.org/10.1186/1472-6963-14-99>
- UNICEF. (2017). Ghana micronutrient survey 2017. *UNICEF: Accra, Ghana*.
- United Nations. (n.d). *Goal 2: Zero Hunger*. Retrieved November 19, 2024 from <https://www.un.org/sustainabledevelopment/hunger/Goal>
- USAID Advancing Nutrition. (2023). *Landscape Analysis of Anemia and Anemia Programming in Northern Ghana*. <https://www.advancingnutrition.org/sites/default/files/2023-11/usaaid-an-landscape-analysis-of-anemia-and-anemia-programing-in-northern-ghana-2023.pdf>
- van de Schoot, R., Depaoli, S., King, R., Kramer, B., Märtens, K., Tadesse, M. G., Vannucci, M., Gelman, A., Veen, D., & Willemsen, J. (2021). Bayesian statistics and modelling. *Nature Reviews Methods Primers*, 1(1), 1.
- Vosti, S. A., Kagin, J., Engle-Stone, R., Luo, H., Tarini, A., Clermont, A., Assiene, J. G., Nankap, M., & Brown, K. H. (2020). Strategies to achieve adequate vitamin A intake for young children: options for Cameroon. *Ann N Y Acad Sci*, 1465(1), 161-180. <https://doi.org/10.1111/nyas.14275>
- Wegmüller, R., Bentil, H., Wirth, J. P., Petry, N., Tanumihardjo, S. A., Allen, L., Williams, T. N., Selenje, L., Mahama, A., Amoahful, E., Steiner-Asiedu, M., Adu-Afarwuah, S., & Rohner, F. (2020). Anemia, micronutrient deficiencies, malaria, hemoglobinopathies and malnutrition in young children and non-pregnant women in Ghana: Findings from a national survey. *PloS one*, 15(1), e0228258. <https://doi.org/10.1371/journal.pone.0228258>
- Wells, J. C., Sawaya, A. L., Wibaek, R., Mwangome, M., Poullas, M. S., Yajnik, C. S., & Demaio, A. (2020). The double burden of malnutrition: aetiological pathways and consequences for health. *The lancet*, 395(10217), 75-88.
- Wessells, K. R., Kumordzie, S. M., Becher, E., Davis, J. N., Nyaaba, K. W., Zyba, S. J., Arnold, C. D., Tan, X., Vosti, S. A., & Adams, K. P. (2024). Acceptability of

multiple micronutrient-fortified bouillon cubes among women and their households in 2 districts in the Northern Region of Ghana. *Current Developments in Nutrition*, 8(1), 102056.

WHO. (2024a). *Anaemia in women and children: WHO Global Anaemia estimates, 2021 Edition*.

https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_childr_en

WHO. (2024b). *Food Fortification* https://www.who.int/health-topics/food-fortification#tab=tab_1

Widaman, K. F., & Helm, J. L. (2023). Exploratory factor analysis and confirmatory factor analysis.



Appendices

Supplemental Table 1a. Sensitivity analysis of individual- and household-level factors associated with perception of study-supplied bouillon cubes among non-index household members

Variables	Categorical levels	Posterior Mean Estimate	95% Credible Interval
Fixed effect			
Acceptance Composite		-0.12	-0.23, 0.00
Districts	Kumbungu	<i>Ref</i>	
	Tolon	-0.01	-0.14, 0.11
Time point of Data Measurement	Early	<i>Ref</i>	
	Late	1.11	0.93, 1.30
Occupation	Farming	<i>Ref</i>	
	Homemaker	-0.06	-0.26, 0.14
	Small business owners	-0.16	-0.33, 0.01
	Government/Private employees	-0.46	-0.73, -0.21
Sex	Female	<i>Ref</i>	
	Male	0.04	-0.16, 0.24
Household Position in Cooking Meals	Never Cook	<i>Ref</i>	
	Primary Cook	0.02	-0.17, 0.22
	Secondary/Occasional cooks	0.16	-0.01, 0.34
Sex of HH	Female	<i>Ref</i>	
	Male	0.18	-0.03, 0.39
Strata	Rural	<i>Ref</i>	
	Urban	0.09	0.00, 0.18
Participant Relationship with HH	Household Head	<i>Ref</i>	
	Wife of HH	0.54	0.32, 0.76
	Parents of HH	0.31	0.07, 0.55

	In-laws and Sibling of HH	0.40	0.16, 0.64
	Sons/Daughters of HH	0.45	0.21, 0.69
Socio-economic index		0.01	-0.03, 0.06
Daily grams of bouillon consumption per HH			
		-0.03	-0.07, 0.02
Study Arm	Group AA	Ref	
	Group BB	0.09	-0.01, 0.16
Interaction Terms			
time point late: Tolon		-0.23	-0.40, -0.06
time point late: Homemaker		0.04	-0.23, 0.30
time point late: Small Business Owners		0.24	0.02, 0.46
time point late: Government/private employees		0.64	0.29, 0.99
time point late: Wife of HH		-0.63	-0.87, -0.40
time point late: Parent of HH		-0.37	-0.70, -0.06
time point late: Siblings/In-laws of HH		-0.42	-0.71, -0.12
time point late: Sons/Daughters of HH		-0.55	-0.87, -0.22
SD(Intercept)		0.04	0.00, 0.12

Note:

This table presents results from a sensitivity analysis of household- and individual-level factors associated with perception of study-supplied bouillon cubes among non-index household members.

Estimates and 95% credible intervals (CrIs) were obtained using a Bayesian linear mixed-effects model with alternative priors. A Normal(0, 1) prior was used for fixed effects, and a Student-t(3, 0, 1) prior was used for the intercept.

Fixed effects included district, time point, occupation, sex, household cooking role, sex of the household head, residential strata (urban or rural), relationship to the household head, socio-economic index, and daily household bouillon consumption (grams).

Interaction terms between the late time point and individual or household-level factors were also included.

A 95% CrI that does not include 0 indicates statistical significance.

Abbreviations: HH, household head; CrI, credible interval.

Supplemental Table 1b. Sensitivity analysis of individual- and household-level factors associated with acceptance of study-supplied bouillon cubes among non-index household members

Parameter	Categorical Levels	Estimate	95% Credible interval (CrI)
Sex	Female	<i>Ref</i>	
	Male	0.05	0.01, 0.09
Occupation	Farming	<i>Ref</i>	
	Homemaker	0.05	-0.01, 0.11
	Small Business Owners	0.06	0.01, 0.11
	Government/private employees	0.06	-0.01, 0.13
Religion	Islam	<i>Ref</i>	
	Christianity/Traditionist	0.12	-0.02, 0.27
Strata	Rural	<i>Ref</i>	
	Urban	-0.09	-0.13, -0.05
Household food security	Food secure	<i>Ref</i>	
	Mildly Food Insecure	-0.07	-0.12, -0.02
	Moderately Food Insecure	-0.01	-0.05, 0.04
	Severely Food Insecure	0.12	0.05, 0.19
Household bouillon consumption (g/day)		-0.02	-0.04, 0.00
Socio-economic index		0.03	0.01, 0.05
Study arm	Group AA	<i>Ref</i>	
	Group BB	0.03	0.00, 0.07
Time point	Early	<i>Ref</i>	
	Late	-0.02	-0.05, 0.02
Intercept (SD)		0.04	0.00, 0.09

Note:

This table presents results from a sensitivity analysis of household- and individual-level factors associated with acceptance of study-supplied bouillon cubes among non-index household members.

Estimates and 95% credible intervals (CrIs) were obtained using a Bayesian linear mixed-effects model with alternative priors. A Normal(0, 1) prior was used for fixed effects, and a Student-t(3, 0, 1) prior was used for the intercept.

Fixed effects included time point, sex, occupation, religion, residential strata (urban or rural), household food insecurity, household bouillon consumption (grams per capita per day), socio-economic index, and study arm.

A 95% CrI that does not include 0 indicates statistical significance.

Abbreviations: HH, household head; CrI, credible interval.

Supplemental material 1. Thematic analysis of focus group discussions (n = 24 FGDs) on perceptions and acceptance of study-supplied bouillon cubes

Themes	Quotes
Theme 1: Improving health and well-being as drivers of acceptance	1. "Since we started using the study-supplied bouillon cubes, I've noticed my children fall sick less often. Their energy levels have improved significantly." (Female, Landlord's Wife, No Formal Education). 2. "The study cubes have been a blessing for my family. My elderly parents feel more energetic and less fatigued." (Male, Landlord, No Formal Education). 3. "We haven't had any health issues since switching to the study cubes. It feels good to know we're getting some nutrients, which are important to our health." (Female, Landlord's Wife, JHS).
Theme 2: Sensory and Practical Experiences	1. "The taste of the study cubes is perfect for our traditional soups and stews. It's not too salty or overpowering." (Female, Landlord's Wife, SHS). 2. "We love the flavor of the study cubes. They make our meals delicious as the way we want the food to taste." (Male, Landlord, No Formal Education). 3. "The study cubes have a great taste that complements our cooking style. Everyone in the family enjoys the meals more now." (Female, Landlord's Wife, JHS).
Theme 3: Cultural Compatibility and Cooking Habits	1. "The study cubes fit perfectly with our traditional recipes. They don't change the original taste of our dishes." (Female, Landlord's Wife, No Formal Education). 2. "We can use the study cubes in all our traditional meals without any issues. They respect our culinary heritage as when used to prepare any food, it tastes nicer." (Male, Landlord, No Formal Education). 3. "It's wonderful that the study cubes complement our traditional cooking methods. They enhance our dishes while preserving their authenticity." (Female, Landlord's Wife, JHS).

Theme 4: Economic benefits of the cube influence their acceptance	1. "The study-supplied cubes save us a lot of money. We don't need to buy additional cubes or even if we will by, we buy in small quantity." (Female, Landlord's Wife, No Formal Education). 2. "Switching to the study cubes has been great for our budget. They're free and give as blood as we do not fall sick frequently any longer." (Male, Landlord, No Formal Education). 3. "We have cut down on healthcare costs since using the study-supplied cubes. They're an economical choice for our family because I do not get blood shortage anymore." (Female, Landlord's Wife, SHS).
Theme 5: Challenges (Perceived Barriers to Acceptance)	1. "My parents were hesitant to switch to the food cook with the study cubes. They prefer sticking to what they know." (Male, Landlord, No Formal Education). 2. "I'm still a bit wary about the long-term effects of consuming fortified products. I want to make sure they're safe for my family." (Female, Landlord's Wife, SHS). 3. "Initially, I thought the study cube will serve as family planning and would reduce our sexual performing ability but as time goes on, I realized I could perform better" (Male, Landlord, No Formal Education). 4. "Sometimes the intervention cubes change the color of our soups to dark, especially the green leafy ones. It's not a major issue, but it's noticeable." (Female, Landlord's Wife, JHS).
Sentimental analysis	Participants expressed both positive and negative sentiments toward the study-supplied bouillon cubes. 1. <i>Positive sentiment:</i> "We trust the fortified cubes completely. They have improved our health and well-being." (Female, Landlord's Wife, No Formal Education). 2. <i>Negative sentiment:</i> "I'm just cautious about how the fortified cubes might affect us in the long run." (Male, Landlord, No Formal Education).
Sub-group analysis	1. As a mother, I'm happy that the fortified cubes are keeping my children healthy." (Female, Landlord's Wife, JHS). 2. The fortified cubes have made it easier for me to provide nutritious meals for my family without worrying about the cost." (Female, Landlord's Wife, No Formal Education). 3. We might not understand all the science behind it, but we can see the positive changes in our health." (Female, Landlord's Wife, No Formal Education).

CHAPTER SEVEN

SPECIFIC OBJECTIVE 3

Randomised Trial of Fortified Bouillon Cubes in Northern Ghana: Associations of the perception and acceptance of the study bouillon cubes among non-index household members with the haemoglobin and iodine status of trial participants

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Abstract

Background and objective: Bouillon cube fortification could help address micronutrient deficiencies (MNDs) in West Africa. This study aimed to examine whether the perceptions and acceptance of intervention bouillon cubes among non-index household members (NIHMs) were associated with the spot urinary iodine concentrations (UIC) and haemoglobin (Hb) of women and pre-school children (PSC) and to assess whether household-level factors modified these associations.

Methods: This study was nested in a doubly masked randomised trial in the Kumbungu and Tolon districts in northern Ghana. Households of non-pregnant, non-lactating women of reproductive age (WRA) and PSC (2–5 years) received rations of multiple micronutrient-fortified bouillon cubes (vitamin A, vitamin B₁₂, folic acid, iron, zinc and iodine) or control bouillon cubes (iodine) for 9 months. One NIHM (≥ 15 years) per household was randomly selected for the study. Household factors, including socio-economic index, food insecurity, baseline household bouillon use, and the age, sex, and education level of the household head, were assessed during the pre-intervention phase. During the first two months (T1, n = 731) and the final two months (T2, n = 796) of intervention, NIHMs were asked about their perceptions and acceptance of the study bouillon using 29 questions, most of which

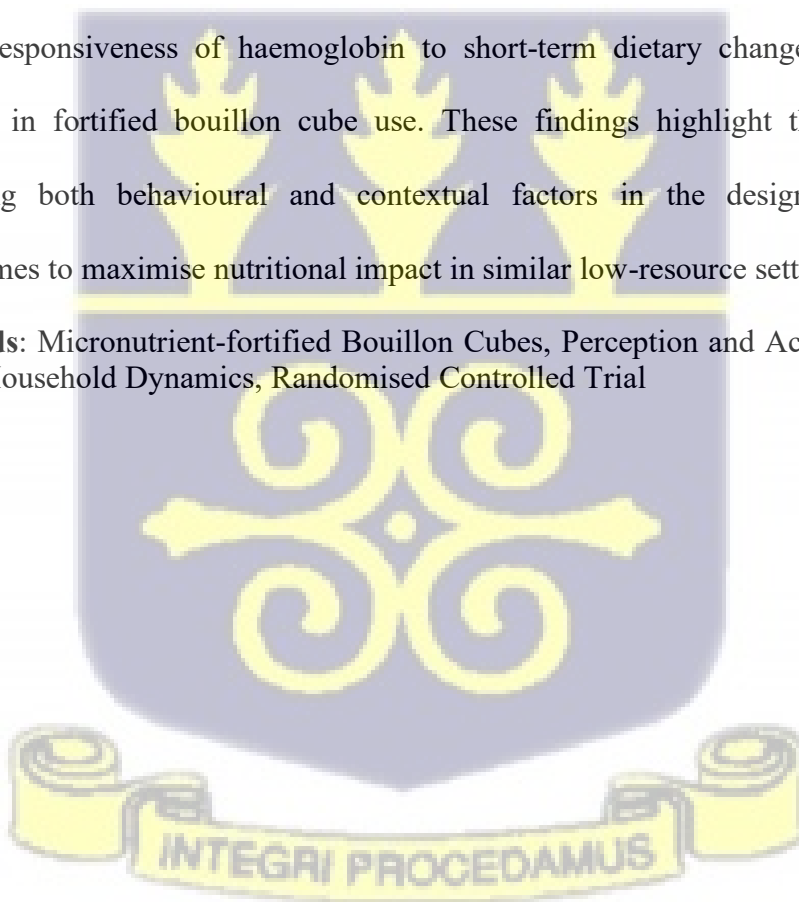
elicited responses on a 5-point Likert scale. Validated questions (8 for perception, 10 for acceptance) were used to compute composite scores for perception and acceptance at both time points. Spot UIC and venous Hb of WRA ($n = 775$) and PSC ($n = 670$) were measured at baseline and endline. Associations between perception, acceptance, and spot UIC were examined using generalised additive mixed models. Effective degrees of freedom (EDF) quantified non-linearity, where $\text{EDF} = 1$ indicated a linear association; $1 < \text{EDF} \leq 2$ indicated weak non-linearity; and $\text{EDF} > 2$ indicated strong non-linearity. The associations of perception and acceptance with Hb were analysed using generalised estimating equations. Models were adjusted for baseline UIC, Hb values, and pre-specified covariates.

Results: No direct significant associations were found between NIHMs' perception or acceptance and Hb concentrations in PSC or WRA; however, these associations were significantly modified by household-level factors. In PSC models at T2, both perception and acceptance scores interacted significantly with household head age (negative direction) and bouillon consumption (positive direction). For instance, the association between perception and Hb was stronger in households with younger heads and higher bouillon use. In WRA models, acceptance interacted negatively with household head age at T1 and positively at T2, as well as positively with socio-economic status and negatively with household size. Perception interacted positively with household bouillon consumption and socio-economic status. For UIC, in PSC models, perception showed a significant non-linear association at T1 ($\text{EDF} = 3.75, p = 0.039$), but not at T2. Acceptance was positively and linearly associated with UIC at both T1 ($\text{EDF} = 1.00, p = 0.015$) and T2 ($\text{EDF} = 1.00, p = 0.013$). In WRA models, both perception and acceptance at T1 and T2 were significantly and non-linearly associated with endline UIC. For perception, EDF was 3.49

($p = 0.007$) at T1 and 3.45 ($p = 0.048$) at T2; for acceptance, EDF was 3.77 ($p = 0.004$) at T1 and 4.33 ($p < 0.001$) at T2. Associations with UIC were modified by household head sex, education, and food-insecurity, with the strongest effects observed in male-headed, low-education, and food-insecure households.

Conclusions: Non-index household members' perceptions and acceptance of fortified bouillon cubes were significantly associated with urinary iodine concentrations among enrolled women of reproductive age and pre-school children, underscoring the indirect household-level influence of behavioural factors on intervention outcomes. No significant associations were observed with haemoglobin concentrations. This finding reflects the limited responsiveness of haemoglobin to short-term dietary changes and household variation in fortified bouillon cube use. These findings highlight the importance of addressing both behavioural and contextual factors in the design of fortification programmes to maximise nutritional impact in similar low-resource settings.

Keywords: Micronutrient-fortified Bouillon Cubes, Perception and Acceptance, Urinary Iodine, Household Dynamics, Randomised Controlled Trial



Introduction

Micronutrient deficiencies (MNDs) remain a significant public health concern, particularly among women and children in low- and middle-income countries. These deficiencies impair cognitive development, reduce immune function, and contribute to morbidity, with long-term effects on educational attainment, productivity, and intergenerational cycles of poverty (Bailey et al., 2015; Olson et al., 2021; Stevens, Paciorek, et al., 2022; WHO, 2024a, 2024c).

In Ghana, particularly in northern Ghana, the burden of MNDs remains high (University of Ghana et al., 2017; USAID Advancing Nutrition, 2023). Inadequate dietary intake is a key driver, though malabsorption and infections, such as malaria, also contribute to poor nutritional status (Abu et al., 2020; Saaka et al., 2021; Wegmüller et al., 2020). According to the Ghana Micronutrient Survey (2017), 40% of PSC in northern Ghana are iron deficient and 31% are vitamin A deficient. Among WRA, iron deficiency affects 22%, with rates exceeding 40% in districts such as Tolon and Kumbungu (University of Ghana et al., 2017).

While Ghana mandates the fortification of wheat flour with iron, zinc, vitamin A, folic acid, and B vitamins, and the fortification of cooking oil with vitamin A, these programmes face challenges including inconsistent industry compliance and low household-level adoption (Ezezika et al., 2021; Gosdin et al., 2021; Nyumuah et al., 2012). These limitations emphasise the need for alternative, context-specific fortification vehicles.

Bouillon cubes, a widely consumed seasoning product in West Africa, have emerged as a promising vehicle for delivering micronutrients through food fortification (Engle-Stone et al., 2021; Matthias et al., 2022). In northern Ghana, more than 90% of

households regularly use bouillon cubes in meal preparation (Kumordzie et al., 2021). Studies in Senegal, Cameroon, Burkina Faso, and parts of Asia have demonstrated the potential of fortified bouillon cubes to improve micronutrient intake and reduce deficiencies without posing a risk of excessive intake among women and children (Adams et al., 2024; Engle-Stone et al., 2014; Spohrer et al., 2015; Thompson et al., 2024). In Ghana, iodine-fortified bouillon cubes alone contributed nearly two-thirds of the iodine intake among school-aged children in the Northern Region (Abizari, Dold, et al., 2017).

Building on this evidence, the Condiment Micronutrient Innovation Trial (CoMIT), a randomised controlled trial, was conducted in the Kumbungu and Tolon districts of northern Ghana (Engle-Stone, Wessells, et al., 2024). The primary objective of CoMIT was to evaluate the effects of household use of multiple micronutrient-fortified bouillon cubes (iodine, vitamin A, folic acid, vitamin B₁₂, iron, and zinc) compared with iodine-only cubes. The trial included three target groups: lactating women (4–18 months postpartum), non-pregnant, non-lactating women of reproductive age (15–49 years), and pre-school children (2–5 years).

While the nutrient content of fortified foods is fundamental to their effectiveness, the success of fortification interventions also depends on household-level behaviours, including perceptions, acceptance, and sustained use. In the context of the CoMIT RCT, where households were the unit of randomisation, the potential impact of micronutrient-fortified bouillon cubes on the nutritional outcomes of enrolled WRA and PSC may be shaped by the behaviours of other household members not enrolled in the trial, such as household heads and cooks. These household members often decide whether, and to what

extent, micronutrient-fortified bouillon cubes are incorporated into daily meal preparation (Christian et al., 2016; Katenga-Kaunda et al., 2022).

To date, no studies have directly quantified the extent to which the perceptions and acceptance of non-enrolled household members affect the nutritional outcomes of trial participants, despite growing recognition of the household as a central unit in fortification efforts (Boatema et al., 2018; Ezezika et al., 2021; Geny et al., 2023; Osendarp et al., 2018). Addressing this gap is crucial for designing interventions that are both effective and sustainable within real-world family settings.

This study therefore examined whether the perceptions and acceptance of household members not enrolled in the CoMIT trial were associated with the micronutrient status of enrolled women and children.

Methods

Overview of the CoMIT Randomised Controlled Trial (RCT) project

The CoMIT was a double-blind, community-based RCT conducted across 16 sites defined by the Ghana Statistical Service, including 14 urban and 14 rural or semi-urban communities located in the Kumbungu and Tolon districts of the Northern Region of Ghana. The primary objective was to evaluate the effects of household use of bouillon cubes fortified with multiple micronutrients (iodine, vitamin A, folic acid, vitamin B₁₂, iron, and zinc) compared with iodine-only cubes on haemoglobin (Hb) and selected micronutrient biomarkers. The trial targeted three physiological groups: non-pregnant, non-lactating women of reproductive age (WRA; 15–49 years; n = 1,028), pre-school

children (PSC; 2–5 years; $n = 690$), and lactating women (LW; 4–18 months postpartum; $n = 690$). The intervention lasted nine months for WRA and PSC, and three months for LW. Detailed methods are reported elsewhere (Engle-Stone, Wessells, et al., 2024).

Randomisation was conducted at the household level using a computer-generated block randomisation scheme (block sizes of 4 or 8). Participants drew group assignments from opaque, numbered envelopes linked to study codes. To maintain blinding, bouillon cubes were identically packaged and labelled (H24, L63, K95, M78), with no indication of nutrient content. Allocation codes were managed independently by the University of Ghana and the University of California, Davis.

Eligibility criteria required WRA, LW, and PSC to have no severe illness, to be able to provide informed consent, and to plan to reside in the study area for the duration of the RCT. For WRA, additional eligibility criteria included a negative malaria rapid diagnostic test, C-reactive protein (CRP) < 5 mg/L at screening, and Hb ≥ 80 g/L at both screening and baseline. PSC were eligible if they had a mid-upper arm circumference (MUAC) ≥ 11.5 cm at recruitment, Hb ≥ 70 g/L, a weight-for-height z-score (WHZ) ≥ -3 SD, and no signs of bilateral pitting oedema at baseline. Households were eligible if they agreed to use only the study bouillon cubes, had no known allergies to the ingredients, and were not concurrently enrolled in another study.

Participants were recruited through door-to-door visits using a random-walk method by trained fieldworkers in collaboration with local health workers. Multiple eligible participants from different physiological groups could be enrolled per household. Oral consent was obtained from household heads, followed by written informed consent

(or thumbprint) from eligible adults. Caregivers provided consent for PSC, and adolescents aged 15–17 years gave assent alongside caregiver consent.

Following baseline assessments, households were assigned to receive either the micronutrient-fortified or iodine-only bouillon cubes. Fortified cubes contained vitamin A (200 µg), folic acid (80 µg), vitamin B₁₂ (1.2 µg), iron (4 mg as ferric pyrophosphate), zinc (3 mg as zinc oxide), and iodine (30 µg as potassium iodate). Control cubes contained iodine only (30 µg as potassium iodate). Potassium iodate was used as the iodine source because it is more stable than sodium iodate under humid and high-temperature conditions, making it suitable for bouillon-cube fortification and storage in tropical environments (Dary & Hurrell, 2006). Bouillon cubes were distributed biweekly based on household size and estimated consumption. Participants were instructed to use only the study-supplied cubes in daily cooking. Adherence was monitored through unannounced spot checks and structured questionnaires during home visits.

Ethical approvals were obtained from the Ghana Health Service Ethical Review Committee (GHS-ERC ID: 024/11/21), the Institutional Review Board of the University of California, Davis (IRB ID: 1837253), and the Ghana Food and Drugs Authority (Certificate No. FDA/CT/2213[1]). The trial was registered at ClinicalTrials.gov (NCT05178407) and the Pan-African Clinical Trials Registry (PACTR202206868437931). These multiple approvals and registrations ensured compliance with both Ghanaian and international ethical standards, protected participant welfare, and enhanced the transparency of the research process.

Study design and approach

This study was a secondary, observational analysis nested within the CoMIT RCT. It examined whether perception and acceptance of study-supplied bouillon cubes among non-enrolled household members (NIHMs) was associated with the micronutrient status of WRA and PSC (or index participant) living in the same households.

A household was defined as a group of individuals who recognise the same head of household, live together, and share living expenses and regularly prepared home meals. Data on haemoglobin, spot urinary iodine concentration (UIC), and household characteristics were extracted from the CoMIT database. These biological and household data were originally collected as part of the main CoMIT trial under approved study protocols and ethical oversight and were accessed for the present nested analysis with appropriate permissions.

Perception and acceptance were measured at two time points during the intervention: early and late phases.

Measurement of haemoglobin and iodine concentration of WRA and PSC in the CoMIT RCT

Haemoglobin (Hb) concentrations and urinary iodine concentrations (UIC) of women of reproductive age (WRA) and pre-school children (PSC) were measured at baseline (T0) and endline (T3) (Figure 3).

For Hb assessment, venous blood samples were collected from WRA in a fasted state and from PSC in a non-fasted state by trained phlebotomists, following standardised biosafety protocols (Brown et al., 2004). Fasting was required for WRA to minimise postprandial variation in haemoglobin readings, whereas PSC were exempted from fasting

for ethical reasons, to avoid prolonged hunger or distress in young children. Haemoglobin concentrations were measured using a HemoCue 301 photometer.

For iodine assessment, midstream urine samples, including spot urine, were collected from participants at T0 and T3. All urine samples were aliquoted into cryovials, stored in cold boxes at 4–8°C in the field, and transported under continuous cold-chain conditions using ice packs to maintain the temperature within this range. Samples were delivered daily to the District Hospital in Tolon for temporary storage at –86°C and later transferred to the University of Ghana for long-term frozen storage prior to analysis. Urinary iodine concentration was analysed at the University of Ghana using a modification of the Sandell–Kolthoff reaction (Global Alliance for Improved Nutrition (GAIN), 2015).

These biomarkers were determined prospectively under standardised trial conditions, which reduced the risk of measurement bias and strengthened their validity for use in this secondary analysis.

Recruitment and selection of non-index household members (NIHMs)

One non-index household member (NIHM) aged ≥ 15 years was selected per household of the index participants (WRA and PSC) during the observation period following the recruitment of the primary participant. An NIHM was eligible for inclusion if they shared meals regularly with the index participant and were willing to remain in the household for the duration of the RCT. The household roster, developed during index participant recruitment, was used to identify eligible NIHMs.

In households with only one NIHM, that individual was automatically enrolled. In households with multiple NIHMs, one was randomly selected using the Kish table method

(Nemeth, 2002). Eligible NIHM provided written informed consent via signature or thumbprint. For those aged 15–17 years who were unmarried and living with a parent or caregiver, assent was obtained alongside caregiver consent.

Each selected NIHM was assigned a unique identification (ID) number that was linked to the ID of the corresponding index participant from their household. NIHM eligibility was maintained as long as at least one index participant remained enrolled in the study, emphasising that NIHM participation was contingent on the enrolment status of the index participant.

Non-index household members: Perception and acceptance measurement

Structured questionnaire interviews were administered at two time points to assess NIHM's perceptions and acceptance of the study-supplied bouillon cubes. Data collection was conducted by ten trained fieldworkers. The assessment time points were: (i) an early intervention phase (T1; n = 731), within the first two months of household exposure to the intervention, and (ii) a late intervention phase (T2; n = 796), within the final two months before households exited the intervention.

The questionnaire consisted of 26 items rated on a five-point Likert scale (1 = completely disagree to 5 = completely agree) and three categorical preference items. The same questionnaire was administered at both T1 and T2.

Perception and acceptance were treated as naturally occurring, non-randomised exposures in this secondary observational analysis. These responses were not assigned by the trial design but rather emerged following household exposure to the intervention.

Background characteristics extracted from CoMIT database

Pre-intervention data included participant and household demographic characteristics such as household-head sex, age, education, and occupation. Additional variables included socio-economic status (measured using the household assets index) (Filmer & Pritchett, 2001), food security (assessed using the Household Food Insecurity Access Scale [HFIAS], following FANTA-3 guidelines) (Coates et al., 2007), and household bouillon cube consumption (g/capita/day). These data were extracted from the CoMIT database for each household included in this analysis. The variables were used as covariates and potential effect modifiers in subsequent models.

Figure 3 presents an overview of the study timeline and the corresponding data-collection activities. All data were collected between January 2023 and June 2024.



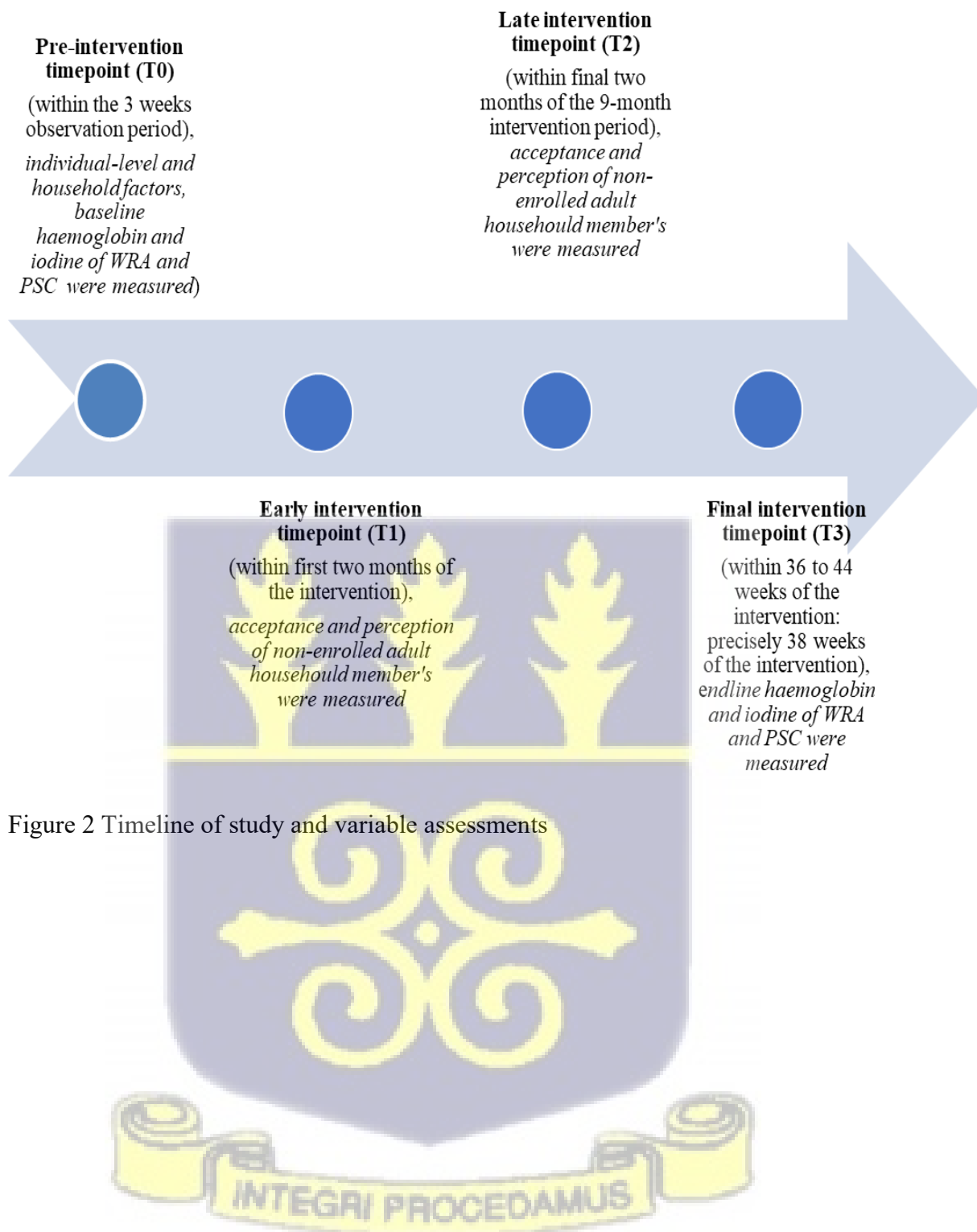


Figure 2 Timeline of study and variable assessments

Use of Perception and Acceptance Composite Scores (Main Predictor Variables)

In this analysis, perception and acceptance were treated as the primary predictor variables. These composite scores were derived from the validated questionnaire developed and psychometrically assessed in the first study manuscript (see **Objective 1 / Chapter 5**). The instrument confirmed a two-factor structure comprising Perception (8 items) and Acceptance (10 items), which formed the basis for constructing the composite scores (see **Table 7.0**).

Items were weighted according to their standardised loadings obtained from the confirmatory factor analysis and then aggregated and normalised to produce continuous composite scores ranging from 1 (lowest) to 5 (highest). These standardised scores represent the strength of each participant's perception and acceptance of the study-supplied micronutrient-fortified bouillon cubes.

Scores were calculated independently for the early (T1) and late (T2) intervention phases and were used in the present analysis as key explanatory variables to examine their associations with the micronutrient status of women and children within the household.

Table 7.0 Standardised factor loadings from the CFA used to create perception and acceptance composite score to early and late intervention time point

Perception		Acceptance	
Items	Standardised factor loadings	Items	Standardised factor loadings
Q1	0.770	Q2	0.525
Q3	0.756	Q5	0.476
Q4	0.719	Q10	0.486
Q6	0.483	Q16	0.538
Q23	0.520	Q17	0.606
Q24	0.464	Q18	0.578
Q26	0.743	Q20	0.607
Q27	0.756	Q25	0.553
		Q28	0.574
		Q29	0.692

Main outcomes and predictors

The primary outcomes were endline Hb concentrations and spot UICs in WRA and PSC. Baseline Hb and spot UIC were included as covariates. The primary predictors were the perception and acceptance scores of NIHM, measured at T1 and T2 of the intervention.

Data analytical approach

Sample size justification

All haemoglobin (Hb) analyses were restricted to the intervention group (WRA: $n = 284$; PSC: $n = 315$; NIHM: $n \geq 285$), as only this group was exposed to the fortified bouillon cubes and therefore able to engage meaningfully with the perception and acceptance constructs. NIHM from unmatched or control households were excluded to avoid exposure misclassification, which could bias the estimated associations (Hernán et al., 2004; Rothman et al., 2008).

In contrast, analyses of spot urinary iodine concentration (UIC) included participants from both intervention and control groups (WRA: $n = 611$; PSC: $n = 641$; NIHM: $n \geq 612$), as all households received bouillon cubes fortified with iodine.

A post hoc sample-size justification was conducted to assess the adequacy of the smallest analytical sample used in the Hb analysis. Because data collection preceded any formal power analysis, this retrospective approach was necessary to evaluate the statistical capacity of the available sample. According to established guidelines for regression-based models, a minimum of 135 participants is required to detect a medium effect size (Cohen's $f^2 = 0.15$) with 80% power and $\alpha = 0.05$, assuming 14 predictors, including main effects

and interaction terms (Cohen, 2013; Lakens, 2021). The smallest analytical sample of 284 WRA with complete endline Hb data exceeds this threshold, indicating that the study is adequately powered to detect meaningful associations and interaction effects.

Statistical analysis

Data preparation and descriptive analysis

To facilitate interpretation, all continuous household-level variables were standardised (mean = 0, SD = 1) (Gelman, 2008). Spot UIC values were natural log-transformed to address strong positive skewness (Hwang et al., 2023). Haemoglobin and the main predictor variables, perception and acceptance scores, were approximately normally distributed based on visual inspection of histograms and Q-Q plots.

Descriptive statistics were used to summarise study variables. Means, standard deviations (SD), medians, and interquartile ranges (IQR) were reported for continuous variables, while categorical variables were described using frequencies and percentages.

Perception and acceptance scores were analysed separately at each time point (T1 and T2) in relation to each outcome variable (Hb and spot UIC), stratified by index participant group (WRA and PSC) for the main analysis and effect modification.

Household-level effect modifiers were selected a priori based on relevant literature. Continuous modifiers included the age of the household head, household size, baseline bouillon cube consumption (g/capita/day), and household socio-economic status (asset index). Categorical modifiers included the sex of the household head (male vs. female), educational level of household head, and household food insecurity status (classified as food secure, mildly, moderately, or severely food insecure).

Modelling of Hb

Generalised Estimating Equations (GEE) were used to evaluate associations between perception or acceptance scores and endline Hb concentrations among WRA and PSC. An exchangeable correlation structure was used to account for within-household clustering (Hubbard et al., 2010). GEE was selected for its robustness in handling intra-household correlations and its use of quasi-likelihood methods for model estimation. GEE estimates marginal, or population-averaged, effects and is well suited for assessing average intervention associations across households without requiring full distributional assumptions (Austin et al., 2024; Liang & Zeger, 1986).

Predefined covariates of biological relevance were included in each model (Wessells et al., 2021; WHO, 2021). For the WRA models, covariates included baseline Hb concentration, the age of WRA, and the age and sex of the corresponding NIHM. For the PSC models, covariates included baseline Hb, age and sex of the child, and age and sex of the NIHM. Results for the Hb models are presented as regression coefficients with corresponding 95% confidence intervals and p-values.

Modelling of spot UIC

Given evidence from the initial exploratory analysis that identified non-linear associations between the log-transformed UICs and NIHM's perception and acceptance scores, generalised additive mixed models (GAMMs) with thin plate regression splines were used to estimate relationships between perception and acceptance scores and log-transformed UIC values. Random intercepts were included to account for household-level clustering, and models were estimated using restricted maximum likelihood (REML) (Wood, 2017).

Covariate selection was guided by biological relevance and empirical evidence from the nutrition and iodine literature (Chowdhury & Turin, 2020; Zimmermann, 2013). Covariates for WRA UIC models included baseline UIC concentration, age of the WRA, and age and sex of the NIHMs. For PSC models, covariates included baseline UIC, age and sex of the child, and age and sex of the NIHMs. The degree of non-linearity in each smooth term was assessed using the effective degrees of freedom (EDF). An $EDF = 1$ indicates a linear relationship, $1 < EDF \leq 2$ indicates weak non-linearity, and $EDF > 2$ indicates strong non-linearity. Model estimates are reported as coefficients, EDF values, 95% confidence intervals, and p-values (Nowakowska et al., 2023; Wood, 2017).

Effect modification and interaction analysis

Interaction terms between perception or acceptance scores and household-level modifiers were included in the Hb model and spot UIC models to assess potential effect modification. For categorical modifiers, an initial screening threshold of $p < 0.10$ was applied, with subgroup analyses performed for significant interactions using a threshold of $p < 0.05$. For continuous modifiers, significance was determined at $p < 0.05$ in the interaction models.

Model Diagnostics

For the GEE models, sensitivity analyses were conducted using alternative correlation structures (independent and autoregressive), which yielded similar results. Robust standard errors were applied throughout to ensure valid inference in the presence of potential misspecification of the correlation structure. For the GAMM models, diagnostic checks included residual analysis, quantile–quantile (Q–Q) plots to assess normality, plots of residuals versus fitted values to assess homoscedasticity, Cook’s distance to detect

influential data points, and variance inflation factors to evaluate multicollinearity. All model assumptions were satisfactorily met based on visual and statistical diagnostics.

Software

All statistical analyses were conducted using R software version 4.3.3. All GEEs were fitted using the `geeglm()` function from the ***geepack*** package (Højsgaard et al., 2006). All GAMMs were fitted using the `gam()` function from the ***mgcv*** package in R. A fixed random seed (`set.seed(123)`) was applied prior to model fitting to ensure reproducibility in any procedures involving stochastic elements, such as smoothing parameter selection or data handling routines internal to `mgcv::gam()` (Wood, 2017).



Results

Background Characteristics

Background characteristics of PSC and NIHM

Table 7.1 presents the background characteristics of PSC and NIHM. Among PSC participants ($n = 328$ intervention; $n = 342$ control), the mean age was 40.0 ± 10.0 months in the intervention group and 43.0 ± 10.4 months in the control group, with an approximately equal sex distribution.

Among NIHM ($n = 341$ intervention; $n = 350$ control), the mean age was 40.0 ± 13.0 years in the intervention group and 40.7 ± 13.0 years in the control group. Females constituted 59.0% of the intervention group and 57.3% of the control group. Over 70% of NIHM did not have formal education. Rural residence was reported for 53.0% of intervention households and 50.9% of control households. The mean household size was 11.34 ± 5.71 in the intervention group and 11.55 ± 6.22 in the control group. Food security was reported in 44.2% of intervention households and 37.1% of control households.

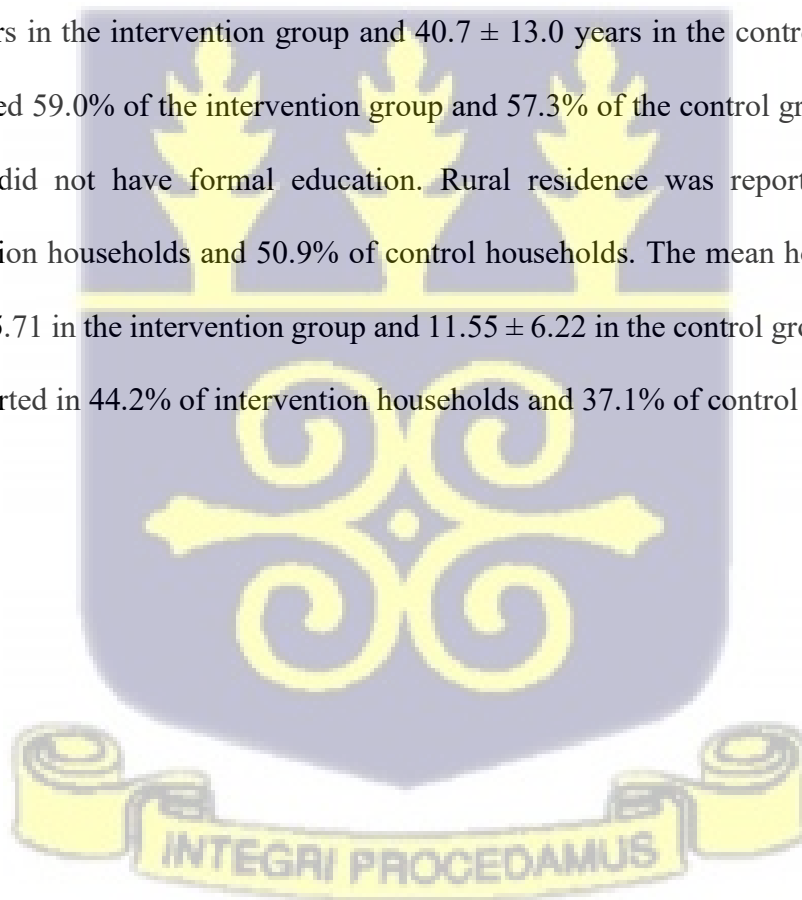


Table 7.1. Background characteristics of pre-school children and non-index household members from the CoMIT project

Variables	Intervention group (Mean $\pm$ SD or % [n])	Control group (Mean $\pm$ SD or % [n])
Pre-school children (2–5 years)		
Number of participants	328	342
Age (months)	40.03 $\pm$ 10.03 [328]	42.99 $\pm$ 10.40 [342]
Sex		
Boy	48.2 [158]	48.8 [167]
Girl	51.8 [170]	51.2 [175]
Non-index household members		
Number of participants	341	350
Sex		
Male	41.0 [112]	42.7 [122]
Female	59.0 [161]	57.3 [164]
Age (years)	39.9 $\pm$ 12.8 [341]	40.7 $\pm$ 13.0 [350]
Education level: no formal education	71.0 [194]	73.0 [209]
Household-level factors		
Number of participants	341	324
Sex of household head		
Male	93.2 [302]	98.0 [335]
Female	6.8 [22]	2.0 [7]
Age of household head (years)	50.3 $\pm$ 15.0 [341]	50.8 $\pm$ 14.6 [350]
Education level of household head		
None	79.8 [260]	76.7 [260]
Basic education (primary or JHS)	9.2 [30]	8.8 [30]
Secondary or higher	11.0 [36]	14.5 [49]
Strata		
Rural	53.0 [174]	50.9 [174]
Urban	47.0 [154]	49.1 [168]
Household size	11.34 $\pm$ 5.71 [328]	11.55 $\pm$ 6.22 [342]
Household bouillon consumption (g/day)	3.28 $\pm$ 7.34 [321]	2.87 $\pm$ 3.55 [335]
HACS	0.06 $\pm$ 1.00 [328]	0.01 $\pm$ 0.99 [342]
HFIAS	2.73 $\pm$ 3.22 [328]	3.50 $\pm$ 3.42 [342]
HFIAS		
Food secure	44.2 [145]	37.1 [127]
Mildly insecure	15.9 [52]	15.2 [52]
Moderately insecure	31.4 [103]	37.7 [129]
Severely insecure	8.5 [28]	9.9 [34]

Note:

Values are presented as means $\pm$ standard deviations (SD) [n] for continuous variables and as percentages with counts (% [n]) for categorical variables.

The intervention group received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12. The control group received bouillon cubes fortified with iodine only.

HACS refers to the Household Asset Composite Score, a proxy indicator of socio-economic status, where higher values represent greater socio-economic status.

HFIAS refers to the Household Food Insecurity Access Scale, a validated proxy for household food insecurity, with categorisation based on Coates et al. (2007).

Household bouillon consumption was calculated as total grams used per day divided by household size, resulting in per capita daily intake (g/day).

Abbreviations: HACS, Household Asset Composite Score; HFIAS, Household Food Insecurity Access Scale.

Background Characteristics of WRA and NIHM.

Table 7.2. presents the background characteristics of WRA and NIHM. Among WRA (n = 387 intervention; n = 380 control), the mean age was 34.3 ± 9.4 years in the intervention group and 33.6 ± 10.0 years in the control group. In the intervention group, 85.0% were married or cohabiting, and 80.0% had no formal education. In the control group, 80.0% were married or cohabiting, and 83.0% had no formal education.

Among NIHM (n = 309 intervention; n = 298 control), the mean age was 39.5 ± 22.4 years in the intervention group and 40.1 ± 15.5 years in the control group, with females comprising 56.0% and 58.0%, respectively. Male-headed households accounted for 95.0% of the intervention group and 98.0% of the control group. The mean age of household heads was 50.3 ± 15.1 years in the intervention group and 50.8 ± 14.6 years in the control group, and 75.0% of household heads in both groups had no formal education. The mean household size was 11.46 ± 6.03 in the intervention group and 12.13 ± 6.24 in the control group.

Table 7.2. Background characteristics of women of reproductive age and non-index household members from the CoMIT project

Variables	Intervention group (Mean $\pm$ SD or % [n])	Control group (Mean $\pm$ SD or % [n])
Women of Reproductive Age		
Number of participants	387	380
Age (years)	34.3 $\pm$ 9.4 [387]	33.6 $\pm$ 10.0 [380]
Marital status		
Married or cohabiting	84.6 [323]	80.4 [299]
Not married	15.4 [59]	19.6 [73]
Non-index household members		
Number of participants	309	298
Sex		
Male	44.0 [136]	42.3 [126]
Female	56.0 [173]	57.7 [172]
Age (years)	39.50 $\pm$ 22.43 [309]	40.10 $\pm$ 15.46 [298]
Educational level		
None	79.9 [247]	83.2 [248]
Basic education (primary or JHS)	6.8 [19]	5.4 [16]
Secondary or higher	13.3 [42]	11.4 [34]
Occupation level		
Farming	45.3 [140]	46.3 [138]
Homemaker	15.2 [47]	16.1 [48]
Self-employed / small business owners	27.5 [85]	28.9 [86]
Government / private employee	12.0 [37]	8.7% [26]
Household-level factors		
Number of participants	387	380
Sex of household head		
Male	94.5 [361]	97.6 [371]
Female	5.5 [21]	2.4 [9]
Age of household head (years)	50.28 $\pm$ 15.10 [326]	50.80 $\pm$ 14.59 [324]
Educational level of household head		
None	74.5 [286]	74.7 [281]
Basic education (primary or JHS)	13.3 [51]	12.5 [47]
Secondary or higher	12.2 [47]	12.8 [48]
District		
Kumbungu	50.1 [194]	49.5 [188]
Tolon	49.9 [193]	50.5 [192]
Strata		
Rural	48.6 [188]	51.1 [194]
Urban	51.4 [199]	48.9 [186]

Household size	11.46 ± 6.03 [387]	12.13 ± 6.24 [380]
Household bouillon consumption (g/day)	3.14 ± 5.67 [378]	2.67 ± 2.36 [370]
HACS	0.06 ± 1.03 [387]	0.10 ± 0.97 [380]
HFIAS		
Food Secure	40.1 [155]	40.8 [155]
Mildly Insecure	18.3 [71]	16.6 [63]
Moderately Insecure	32.8 [127]	35.8 [138]
Severely Insecure	8.8 [34]	6.8 [26]

Note:

Values are presented as means ± standard deviations (SD) [n] for continuous variables and as percentages with counts (% [n]) for categorical variables.

Minor discrepancies in the totals across some variables are due to missing background data for a small number of participants. Missing values were excluded from the denominators for those specific variables.

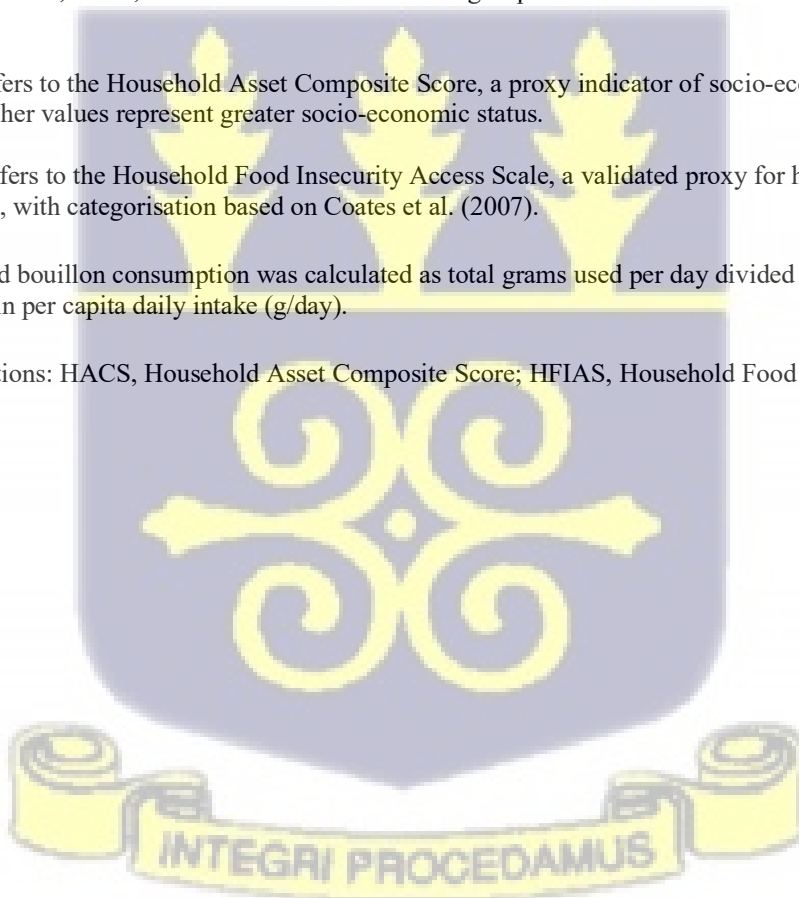
The intervention group received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12. The control group received bouillon cubes fortified with iodine only.

HACS refers to the Household Asset Composite Score, a proxy indicator of socio-economic status, where higher values represent greater socio-economic status.

HFIAS refers to the Household Food Insecurity Access Scale, a validated proxy for household food insecurity, with categorisation based on Coates et al. (2007).

Household bouillon consumption was calculated as total grams used per day divided by household size, resulting in per capita daily intake (g/day).

Abbreviations: HACS, Household Asset Composite Score; HFIAS, Household Food Insecurity Access Scale.



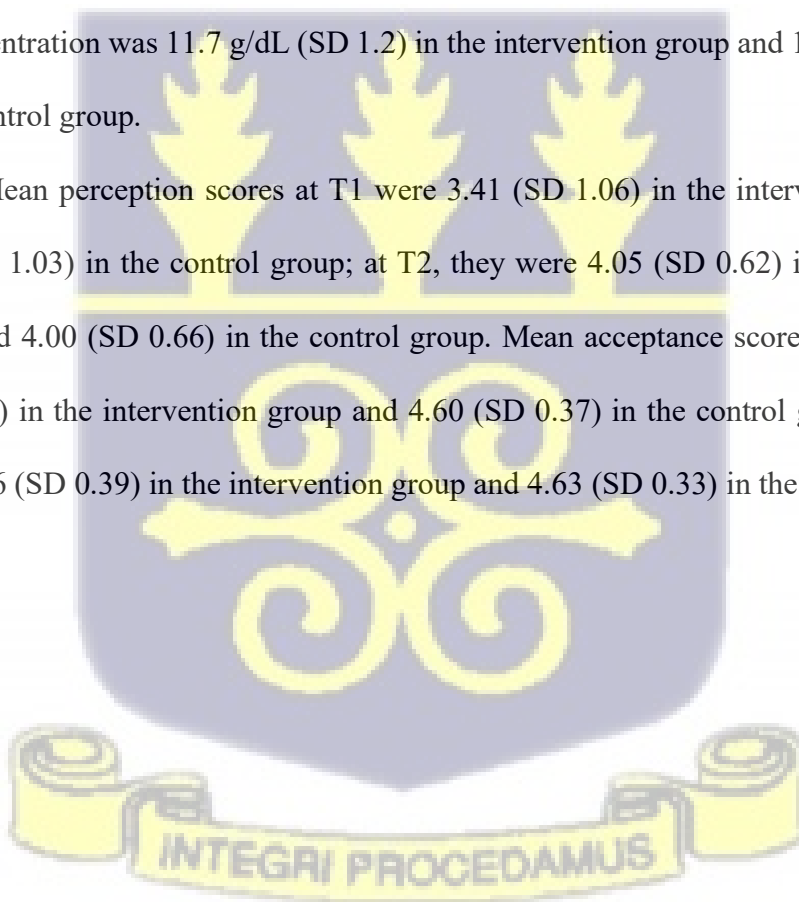
Micronutrient status of PSC and perception and acceptance of NIHMs

Table 7.3 presents the micronutrient status of PSC and the perception and acceptance scores of NIHMs.

At baseline, the median urinary iodine concentration (UIC) was 106.8 µg/L (IQR: 57.5–188.2) in the intervention group and 109.0 µg/L (IQR: 69.3–187.8) in the control group. At endline, the median UIC was 130.7 µg/L (IQR: 78.1–229.6) in the intervention group and 140.4 µg/L (IQR: 87.1–251.2) in the control group.

The mean haemoglobin (Hb) concentration at baseline was 11.4 g/dL (SD 1.3) in the intervention group and 11.5 g/dL (SD 1.2) in the control group. At endline, the mean Hb concentration was 11.7 g/dL (SD 1.2) in the intervention group and 11.8 g/dL (SD 1.0) in the control group.

Mean perception scores at T1 were 3.41 (SD 1.06) in the intervention group and 3.53 (SD 1.03) in the control group; at T2, they were 4.05 (SD 0.62) in the intervention group and 4.00 (SD 0.66) in the control group. Mean acceptance scores at T1 were 4.55 (SD 0.38) in the intervention group and 4.60 (SD 0.37) in the control group; at T2, they were 4.56 (SD 0.39) in the intervention group and 4.63 (SD 0.33) in the control group.



Micronutrient status of pre-school children and the perception and acceptance scores of non-index household members from the CoMIT project

Variables	Intervention group			Control group		
	n	Median	Interquartile range (IQR)	n	Median	Interquartile range (IQR)
Baseline UIC (µg/L)	328	106.8	57.5 – 188.2	342	109.0	69.3–187.8
Endline UIC (µg/L)	317	130.7	78.1 – 229.6	324	140.4	87.1 – 251.2.0
		Mean	SD		Mean	SD
Baseline Hb concentration (g/dL)	328	11.4	1.28	342	11.50	1.21
Endline Hb concentration (g/dL)	315	11.7	1.15	323	11.80	1.02
Perception_T1	285	3.41	1.06	289	3.53	1.03
Perception_T2	302	4.05	0.62	310	4.00	0.66
Acceptance_T1	285	4.55	0.38	289	4.60	0.37
Acceptance_T2	302	4.56	0.39	310	4.63	0.33

Note:

Variables are reported as medians with interquartile ranges (IQR: 1st–3rd quartile) for urinary iodine concentration (UIC), and as means with standard deviations (SD) for haemoglobin concentration (Hb), perception, and acceptance.

The intervention group received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12. The control group received bouillon cubes fortified with iodine only.

T1 refers to the early intervention phase, when perception and acceptance of non-index household members (NIHMs) were measured within the first two months of receiving the cubes. T2 refers to the late intervention phase, measured within the last two months of the nine-month trial.

Abbreviations: UIC, urinary iodine concentration; Hb, haemoglobin concentration; SD, standard deviation; IQR, interquartile range



Micronutrient status of WRA and perception and acceptance of NIHMs

Table 7.4 presents the micronutrient status of WRA and the perception and acceptance scores of NIHMs.

At baseline, the median UIC was 98.8 $\mu\text{g/L}$ (IQR: 54.0–175.3) in the intervention group and 95.7 $\mu\text{g/L}$ (IQR: 52.2–170.7) in the control group. At endline, the median UIC was 120.8 $\mu\text{g/L}$ (IQR: 66.0–193.9) in the intervention group and 121.8 $\mu\text{g/L}$ (IQR: 72.7–192.7) in the control group.

The mean Hb concentration at baseline was 12.95 g/dL (SD 1.22) in the intervention group and 12.97 g/dL (SD 1.27) in the control group. At endline, the mean Hb concentration was 12.89 g/dL (SD 1.20) in the intervention group and 12.86 g/dL (SD 1.16) in the control group.

Mean perception scores at T1 were 3.44 (SD 1.03) in the intervention group and 3.49 (SD 1.04) in the control group; at T2, they were 4.04 (SD 0.58) in the intervention group and 4.13 (SD 0.54) in the control group. Mean acceptance scores at T1 were 4.57 (SD 0.39) in the intervention group and 4.62 (SD 0.36) in the control group; at T2, they were 4.60 (SD 0.37) in the intervention group and 4.60 (SD 0.33) in the control group.

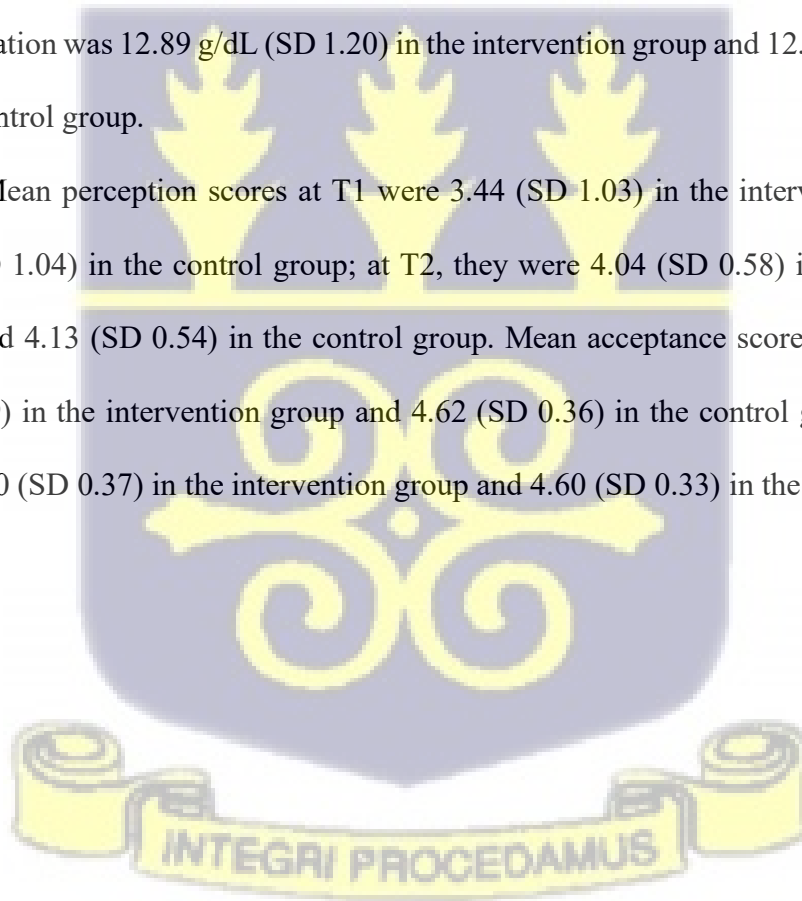


Table 7.4: Micronutrient status of women of reproductive age and perception or acceptance scores of non-index household members in the CoMIT project

Variables	Intervention group			Control group		
	n	Median	Interquartile range	n	Median	Interquartile range
Baseline UIC (µg/L)	298	98.8	54.0 – 175.3	313	95.7	52.2 – 170.7
Endline UIC (µg/L)	298	120.8	66.0 – 193.9	313	121.8	72.7 – 192.7
		Mean	SD		Mean	SD
Baseline Hb concentration (g/dL)	384	12.95	1.22	378	12.97	1.27
Endline Hb concentration (g/dL)	284	12.89	1.20	291	12.86	1.16
Perception_T1	320	3.44	1.03	322	3.49	1.04
Perception_T2	335	4.04	0.58	327	4.13	0.54
Acceptance_T1	320	4.57	0.39	322	4.62	0.36
Acceptance_T2	335	4.60	0.37	327	4.60	0.33

Note:

Variables are reported as medians with interquartile ranges (IQR: 1st–3rd quartile) for urinary iodine concentration (UIC), and as means with standard deviations (SD) for haemoglobin concentration (Hb), perception, and acceptance.

The intervention group received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12. The control group received bouillon cubes fortified with iodine only.

T1 refers to the early intervention phase, when perception and acceptance of non-index household members (NIHMs) were measured within the first two months of receiving the cubes. T2 refers to the late intervention phase, measured within the last two months of the nine-month trial.

Abbreviations: UIC, urinary iodine concentration; Hb, haemoglobin concentration; SD, standard deviation; IQR, interquartile range



Association between perception or acceptance among NIHM's and endline Hb concentrations in PSC in the CoMIT project

Table 7.5 presents the association between the perception or acceptance scores among NIHM's at T1 and T2 and endline Hb concentrations in PSC in the intervention group. Perception at T1 (Estimate = 0.002; 95% CI [-0.146, 0.150]) and T2 (Estimate = 0.029; 95% CI [-0.209, 0.268]) were not significantly associated with endline Hb concentrations. Acceptance at T1 (Estimate = -0.027; 95% CI [-0.200, 0.146]) and T2 (Estimate = 0.077; 95% CI [-0.093, 0.246]) showed no significant associations with endline Hb concentrations.



Table 7.5. Association between perception or acceptance scores among non-index household members and endline haemoglobin concentration in pre-school children from the CoMIT project

Predictor / Term	Estimate	95% CI (Lower, Upper)	P-value
<i>Early (T1) Intervention phase</i>			
Perception	0.002	(-0.146, 0.150)	0.97
Acceptance	-0.027	(-0.200, 0.146)	0.75
<i>Late (T2) Intervention phase</i>			
Perception	0.029	(-0.209, 0.268)	0.81
Acceptance	0.077	(-0.093, 0.246)	0.37

Note:

Analysis was restricted to the intervention group only. The intervention group received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12.

Estimates represent the coefficient values for each predictor, indicating the strength and direction of the association. The 95% confidence intervals (CIs) provide a range within which the true effect size is expected to fall.

P-values indicate the significance level of each predictor; values < 0.05 were considered statistically significant.

Models were adjusted for baseline haemoglobin concentration, age and sex of pre-school children (PSC), and age and sex of non-index household members (NIHMs). Analysis was conducted using Generalised Estimating Equations (GEE).



Association between perception or acceptance among NIHM's and endline spot UIC of PSC in the CoMIT project

Table 7.6 presents the associations between the perception or acceptance scores among NIHM's at T1 and T2 and endline spot UIC in PSC across both study groups. At T1, perception showed a significant non-linear association with endline spot UIC ($EDF = 3.75$; $F = 2.86$; $p = 0.04$). At T2, perception was not significantly associated with endline spot UIC ($EDF = 2.36$; $F = 1.89$; $p = 0.13$). Acceptance showed significant linear associations with endline spot UIC at both time points: T1 ($EDF = 1.00$; $F = 6.16$; $p = 0.02$) and T2 ($EDF = 1.00$; $F = 6.43$; $p = 0.01$).



Table 7.6. Association between non-index household members' perception or acceptance scores and endline spot urinary iodine concentration in pre-school children from the CoMIT project

Variables	EDF ¹	F-value	P-value
<i>Early (T1) Intervention phase</i>			
Perception	3.75	2.86	0.04*
Acceptance	1.00	6.16	0.02*
<i>Late (T2) Intervention phase</i>			
Perception	2.32	1.89	0.13
Acceptance	1.00	6.43	0.01*

Note:

¹EDF (Effective Degrees of Freedom) indicates the complexity of the association, where an EDF of 1 representing a linear association and an EDF >1 indicating a non-linear association.

P-values indicate the significance level for the smooth term; values < 0.05 were considered statistically significant and are marked with an asterisk (*).

Models were adjusted for baseline spot urinary iodine concentration, age and sex of pre-school children (PSC), and age and sex of non-index household members (NIHMs).

Analysis was conducted using Generalised Additive Mixed Models (GAMM).



Association between perception or acceptance among NIHMs and endline Hb concentrations of WRA in the CoMIT project

Table 7.7 presents the association between the perception or acceptance scores among NIHMs at T1 and T2 and endline Hb concentrations in WRA in the intervention group. Perception at T1 (Estimate = -0.087 ; 95% CI [$-0.246, 0.072$]) and T2 (Estimate = -0.065 ; 95% CI [$-0.226, 0.136$]) were not significantly associated with endline Hb concentrations. Acceptance at T1 (Estimate = 0.102 ; 95% CI [$-0.182, 0.385$]) and T2 (Estimate = 0.031 ; 95% CI [$-0.074, 0.135$]) showed no significant associations with endline Hb concentrations.



Table 7.7. Association between perception or acceptance scores among non-index household members and endline haemoglobin concentration in women of reproductive age from the intervention group of the CoMIT project

Predictor / Term	Estimate	95% CI (Lower, Upper)	P-value
<i>Early (T1) Intervention phase</i>			
Perception	-0.087	(-0.246, 0.072)	0.283
Acceptance	0.102	(-0.182, 0.385)	0.483
<i>Late (T2) Intervention phase</i>			
Perception	-0.065	(-0.226, 0.136)	0.527
Acceptance	0.031	(-0.074, 0.135)	0.565

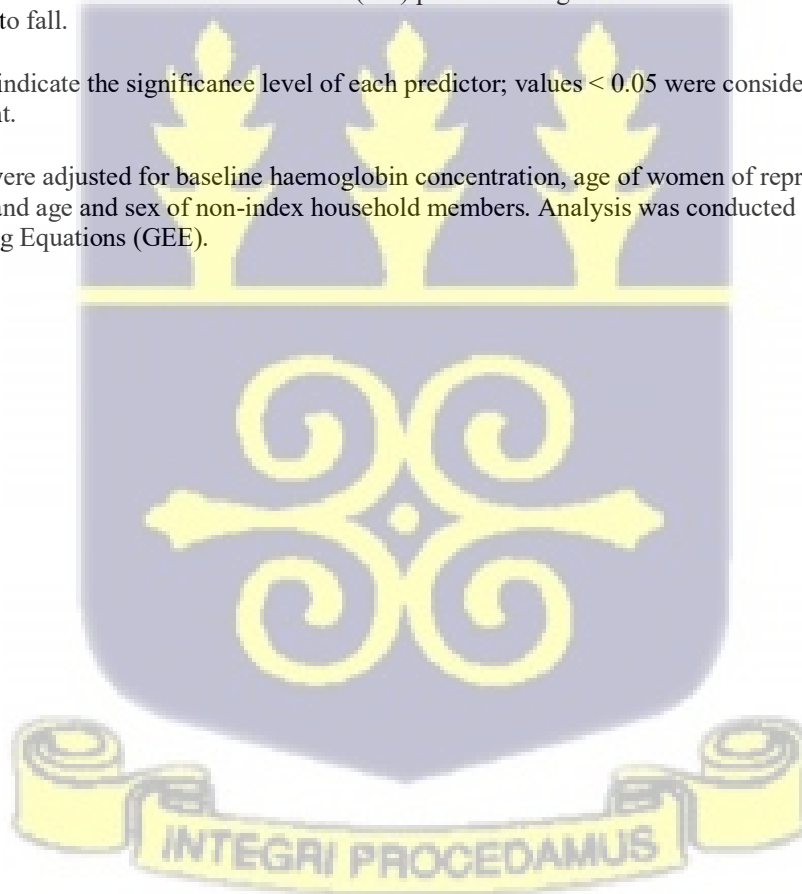
Note:

Analysis was restricted to the intervention group only. The intervention group received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12.

Estimates represent the coefficient values for each predictor, indicating the strength and direction of the association. The 95% confidence intervals (CIs) provide a range within which the true effect size is expected to fall.

P-values indicate the significance level of each predictor; values < 0.05 were considered statistically significant.

Models were adjusted for baseline haemoglobin concentration, age of women of reproductive age (WRA), and age and sex of non-index household members. Analysis was conducted using Generalised Estimating Equations (GEE).



Association between NIHM's perception or acceptance scores and endline Spot UIC in WRA in the CoMIT project

Table 7.8 presents the associations between perception or acceptance scores among NIHM's at T1 and T2 and endline spot UIC in WRA across both study groups. Perception showed statistically significant non-linear associations with endline spot UIC at T1 (EDF = 3.49; $F = 4.09$; $p = 0.007$) and T2 (EDF = 3.45; $F = 2.25$; $p = 0.048$). Acceptance was also significantly associated with endline spot UIC at both T1 (EDF = 3.77; $F = 3.89$; $p = 0.004$) and T2 (EDF = 4.33; $F = 5.20$; $p < 0.001$), with non-linear patterns observed at each time point.



Table 7.8. Association between non-index household members' perception or acceptance scores and endline spot urinary iodine concentration in women of reproductive age from the CoMIT project

Predictor Variables	EDF ¹	F-value	P-value
<i>Early (T1) Intervention phase</i>			
Perception	3.49	4.09	0.007*
Acceptance	3.77	3.98	0.004*
<i>Late (T2) Intervention phase</i>			
Perception	3.45	2.25	0.048*
Acceptance	4.33	5.20	<0.001*

Note:

¹EDF (Effective Degrees of Freedom) indicates the complexity of the association, where an EDF of 1 representing a linear association and an EDF >1 indicating a non-linear association.

P-values represent the significance level of the smooth term. Values < 0.05 were considered statistically significant and are marked with an asterisk (*).

Each model was adjusted for baseline UIC, age, educational level, and marital status of women of reproductive age (WRA), as well as the age and sex of non-index household members.

Analysis was conducted using Generalised Additive Mixed Models (GAMM).



Household factors as effect modifiers of the association between NIHMs' perception or acceptance and endline Hb levels of PSC in the CoMIT project

Table 7.9 presents the results of effect modification analyses by household factors on the association between perception or acceptance scores among NIHMs and endline Hb concentrations in PSC within the intervention group. At T1, no statistically significant interactions were observed between household factors and either perception or acceptance ($p > 0.10$ for categorical variables; $p > 0.05$ for continuous variables).

At T2, perception showed significant interactions with the age of the household head (Estimate = -0.225 ; 95% CI [-0.393 , -0.058]; $p = 0.008$), household bouillon cube consumption (g/day) (Estimate = 1.309 ; 95% CI [0.799 , 1.819]; $p < 0.001$), and household size (Estimate = 0.355 ; 95% CI [0.076 , 0.634]; $p = 0.013$). Acceptance showed significant interactions with the age of the household head (Estimate = -0.179 ; 95% CI [-0.306 , -0.053]; $p = 0.005$) and household bouillon cube consumption (Estimate = 0.998 ; 95% CI [0.636 , 1.361]; $p < 0.001$).

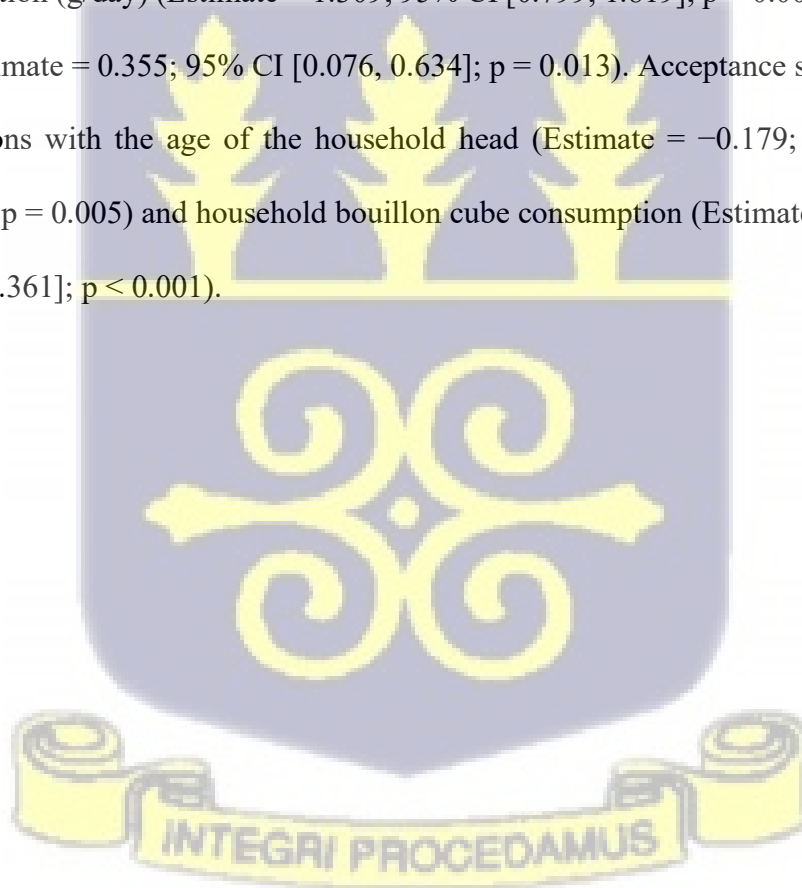


Table 7.9. Household-level factors as effect modifiers of the association between non-index household members' perception or acceptance scores and endline haemoglobin concentration in pre-school children from the CoMIT project

Predictor/Term	Estimate	95% CI (Lower, Upper)	P-value
<i>Perception at T1: Interaction Effects</i>			
Age of household head	0.105	(-0.063, 0.275)	0.217
Educational level of household head	-0.155	(-0.394, 0.085)	0.205
Household bouillon consumption (g/capita/day)	-0.149	(-0.874, 0.575)	0.686
HACS	-0.115	(-0.269, 0.039)	0.143
HFIAS	0.040	(-0.102, 0.183)	0.580
Household size	0.116	(-0.075, 0.307)	0.234
<i>Acceptance at T1: Interaction Effects</i>			
Age of Household Head	-0.068	(-0.227, 0.091)	0.401
Educational level of household head	-0.072	(-0.353, 0.210)	0.618
Household bouillon consumption (g/capita/day)	0.260	(-0.842, 1.362)	0.644
HACS	0.126	(-0.071, 0.323)	0.211
HFIAS	-0.029	(-0.223, 0.162)	0.765
Household size	-0.219	(-0.443, 0.004)	0.055
<i>Perception at T2: Interaction Effects</i>			
Age of household head	-0.225	(-0.393, -0.058)	0.008
Educational level of household head	0.031	(-0.243, 0.310)	0.826
Household bouillon consumption (g/capita/day)	1.309	(0.799, 1.819)	<0.001
HACS	0.001	(-0.273, 0.273)	0.999
HFIAS	-0.089	(-0.335, 0.156)	0.476
Household size	0.355	(0.076, 0.634)	0.013
<i>Acceptance at T2: Interaction Effects</i>			
Age of Household Head	-0.179	(-0.306, -0.053)	0.005
Educational level of household head	0.232	(-0.065, 0.529)	0.126
Household bouillon consumption (g/capita/day)	0.998	(0.636, 1.361)	<0.001
HACS	0.094	(-0.094, 0.282)	0.327
HFIAS	-0.006	(-0.179, 0.167)	0.945
Household size	0.122	(-0.088, 0.332)	0.254

Note:

Analysis was restricted to the intervention group only, which received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12.

T1 refers to the early intervention phase, when perception and acceptance of non-index household members (NIHMs) were measured within the first two months of receiving the cubes. T2 refers to the late intervention phase, measured within the last two months of the nine-month trial.

Estimates represent the coefficient values for each predictor, indicating the strength and direction of the association. The 95% confidence intervals (CIs) provide a range within which the true effect size is expected to fall.

P-values reflect the significance of interaction effects. Significant terms were defined as $p < 0.1$ for categorical variables and $p < 0.05$ for continuous variables and are marked with an asterisk (*).

Models were adjusted for baseline haemoglobin levels, age and sex of the child.

HACS refers to the Household Asset Composite Score, a proxy indicator of socio-economic status, where higher values reflect greater household wealth.

HFIAS refers to the Household Food Insecurity Access Scale, a proxy indicator of household food insecurity, based on Coates et al. (2007).

Abbreviations: HACS, Household Asset Composite Score; HFIAS, Household Food Insecurity Access Scale.



Household factors as effect modifiers of the association between NIHM's perception or acceptance and endline spot UIC of PSC in the CoMIT project

Table 7.10 presents the results of effect modification analyses by household factors on the association between perception or acceptance scores among NIHM's and endline spot UIC in PSC across both study groups.

At T1, perception showed statistically significant interactions with the educational level of the household head (EDF = 1.00; $F = 3.77$; $p = 0.055$), the HFIAS (EDF = 1.26; $F = 3.66$; $p = 0.045$), and the sex of the household head (EDF = 3.72; $F = 2.71$; $p = 0.036$). Subgroup analyses (**Table 7.11**) indicated that these effects were significant among households where the head had attained a basic education (EDF = 1.00; $F = 6.14$; $p = 0.040$), those classified as moderately food insecure (EDF = 1.06; $F = 6.43$; $p = 0.020$), and male-headed households (EDF = 4.04; $F = 2.56$; $p = 0.040$).

For acceptance at T1, significant interactions were observed with household size (EDF = 1.00; $F = 4.45$; $p = 0.038$) and the sex of the household head (EDF = 1.07; $F = 5.17$; $p = 0.022$). However, subgroup analyses by sex showed no significant interaction effects. No statistically significant interactions were observed for household bouillon cube consumption, HACS (socio-economic status), or HFIAS (household food insecurity) in relation to acceptance at T1.

At T2, no significant interactions were observed between perception and any of the household factors. However, acceptance showed a statistically significant interaction with household bouillon cube consumption (g/capita/day) (EDF = 1.00; $F = 4.24$; $p = 0.042$).

Table 7.10. Household-level factors as effect modifiers of the association between non-index household members' perception and acceptance scores and endline spot urinary iodine concentration in pre-school children from the CoMIT project

Variables	EDF ¹	F-Value	P-value
<i>Perception at T1: Interaction Effects</i>			
Educational level of household head	1.00	3.77	0.055*
Household size	1.00	1.68	0.198
Household bouillon consumption (g/capita/day)	1.00	0.45	0.53
HFIAS ²	1.26	3.66	0.045*
HACS ³	1.00	0.05	0.824
Sex of household head	3.72	2.71	0.036*
<i>Acceptance at T1: Interaction Effects</i>			
Educational level of household head	1.00	0.36	0.548
Household size	1.00	4.45	0.038*
Household bouillon consumption (g/capita/day)	1.00	0.36	0.558
HFIAS	2.00	1.56	0.219
HACS	1.01	0.00	0.997
Sex of Household head	1.07	5.17	0.022*
<i>Perception at T2: Interaction Effects</i>			
Educational level of household head	1.00	0.74	0.39
Household size	1.00	0.01	0.94
Household bouillon consumption (g/capita/day)	1.44	0.42	0.47
HFIAS	1.87	0.94	0.43
HACS	1.00	1.32	0.25
Sex of Household head	1.00	1.07	0.30
<i>Acceptance at T2: Interaction Effects</i>			
Educational level of household head	2.00	0.57	0.55
Household size	1.30	0.77	0.51
Household bouillon consumption (g/capita/day)	1.00	4.24	0.042*
HFIAS	1.00	2.05	0.16
HACS	1.23	0.32	0.64
Sex of household head	1.00	0.05	0.83

Note:

¹EDF (Effective Degrees of Freedom) reflects the complexity of the association, where an EDF of 1 indicates a linear relationship, and an EDF greater than 1 indicates a non-linear association.

P-values indicate the significance level for the smooth term or interaction effect. Significant terms were defined as $p < 0.1$ for categorical variables and $p < 0.05$ for continuous variables and are marked with an asterisk (*).

HACS refers to the Household Asset Composite Score, a proxy indicator of household socio-economic status, where higher values reflect greater wealth.

HFIAS refers to the Household Food Insecurity Access Scale, a validated proxy for food insecurity, categorised as food secure, mildly insecure, moderately insecure, and severely insecure (Coates et al., 2007).

All models included household-level factors as main effects. Covariates adjusted for in each model included baseline urinary iodine concentration (UIC), age, sex, as well as the age and sex of non-index household members.

Analysis was conducted using Generalised Additive Mixed Models.

Abbreviations: EDF, effective degrees of freedom; HACS, Household Asset Composite Score; HFIAS, Household Food Insecurity Access Scale.

Table 7.11. Subgroup analysis of the modification effects of household-level factors on the association between non-index household members' perception or acceptance scores and endline spot urinary iodine concentration in pre-school children from the CoMIT project

Variables	EDF ¹	F-value	P-value
<i>Perception at T1: Interaction Effects</i>			
Household head education = No formal education	2.64	0.75	0.35
Household head education = <i>Basic education</i>	1.00	6.14	0.04*
Household head education = SHS & higher	1.00	2.30	0.16
Household food insecurity = Food Secure	2.44	0.80	0.50
Household food insecurity = Mildly Food Insecure	2.03	0.18	0.47
Household food insecurity = <i>Moderately insecure</i>	1.06	6.43	0.02*
Household food insecurity = Severely insecure	1.00	0.02	0.90
Sex = <i>Male</i>	4.04	2.56	0.04*
Sex = Female	1.59	0.25	0.79
<i>Acceptance at T1: Interaction Effect</i>			
Sex = Male	2.43	1.24	0.35
Sex = Female	1.00	0.77	0.54

Note:

¹EDF (Effective Degrees of Freedom) indicates the complexity of the association, where an EDF of 1 represents a linear association and an EDF greater than 1 represents a non-linear association.

P-values were derived from Generalised Additive Mixed Models used in subgroup analysis. A $p < 0.05$ was considered statistically significant and is marked with an asterisk (*).



Household factors as effect modifiers of the association between NIHM's perception or acceptance and endline Hb concentration of WRA in the CoMIT project

Table 7.12 presents the results of effect modification analyses by household factors on the association between perception or acceptance scores among NIHM's and endline Hb concentrations in WRA within the intervention group.

At T1, no statistically significant interactions were observed between household factors and perception scores (all p-values > 0.05 for continuous variables). For acceptance at T1, a significant interaction was found with the age of the household head (Estimate = -0.256; 95% CI [-0.393, -0.119]; $p < 0.001$). All other interactions for acceptance at T1 were not statistically significant (p-values > 0.10 for categorical variables; p-values > 0.05 for continuous variables).

At T2, significant interactions were observed between perception scores and household bouillon cube consumption (Estimate = 0.458; 95% CI [0.067, 0.849]; $p = 0.022$) and with socio-economic status (Estimate = 0.354; 95% CI [0.109, 0.559]; $p = 0.004$). For acceptance at T2, significant interactions were observed with the age of the household head (Estimate = 0.334; 95% CI [0.054, 0.614]; $p = 0.019$), socio-economic status (Estimate = 0.211; 95% CI [0.015, 0.376]; $p = 0.033$), and household size (Estimate = -0.425; 95% CI [-0.715, -0.135]; $p = 0.004$). No other interaction terms at T2 reached statistical significance.



Table 7.12. Household-level factors as effect modifiers of the association between non-index household members' perception or acceptance scores and endline haemoglobin concentration in women of reproductive age from the CoMIT project

Variables	Estimate	95% CI (Lower, Upper)	P-value
<i>Perception at T1: Interaction Effects</i>			
Age of household head	-0.057	(-0.300, 0.185)	0.643
Educational level of household head	-0.081	(-0.331, 0.170)	0.529
Household bouillon consumption (g/capita/day)	0.047	(-0.271, 0.365)	0.774
HACS ⁴	0.041	(-0.155, 0.237)	0.683
HFIAS ⁵	0.122	(-0.089, 0.335)	0.258
Household size	0.147	(-0.017, 0.311)	0.078
<i>Acceptance at T1: Interaction Effects</i>			
Age of Household Head	-0.256	(-0.393, -0.119)	<0.001*
Educational level of household head	0.050	(-0.365, 0.466)	0.812
Household bouillon consumption (g/capita/day)	-0.219	(-0.690, 0.252)	0.362
HACS	0.050	(-0.290, 0.391)	0.772
HFIAS	-0.165	(-0.505, 0.174)	0.339
Household size	-0.253	(-0.568, 0.063)	0.116
<i>Late (T2) Intervention Phase</i>			
<i>Perception at T2: Interaction Effects</i>			
Age of household head	0.158	(-0.167, 0.484)	0.341
Educational level of household head	0.333	(-0.075, 0.742)	0.110
Household bouillon consumption (g/capita/day)	0.458	(0.067, 0.849)	0.022*
HACS	0.354	(0.109, 0.559)	0.004*
HFIAS	0.233	(-0.115, 0.581)	0.189
Household size	-0.216	(-0.611, 0.180)	0.286
<i>Acceptance at T2: Interaction Effects</i>			
Age of Household Head	0.334	(0.054, 0.614)	0.019*
Educational level of household head	0.089	(-0.312, 0.491)	0.663
Household bouillon consumption (g/capita/day)	-0.285	(-0.736, 0.166)	0.216
HACS	0.211	(0.015, 0.376)	0.033*
HFIAS	-0.033	(-0.279, 0.212)	0.790
Household size	-0.425	(-0.715, -0.135)	0.004*

Note:

Analysis was restricted to the intervention group only, which received multiple micronutrient-fortified bouillon cubes containing iron, iodine, zinc, vitamin A, folate, and vitamin B12.

T1 refers to the early intervention phase, when perception and acceptance of non-index household members (NIHMs) were measured within the first two months of receiving the cubes. T2 refers to the late intervention phase, measured within the last two months of the nine-month trial.

Estimates represent the coefficient values for each predictor, indicating the strength and direction of the association. The 95% confidence intervals (CIs) provide a range within which the true effect size is expected to fall.

P-values reflect the significance of interaction effects. Significant terms were defined as $p < 0.1$ for categorical variables and $p < 0.05$ for continuous variables and are marked with an asterisk (*).

Models were adjusted for baseline haemoglobin levels, age and sex of the child.

HACS refers to the Household Asset Composite Score, a proxy indicator of socio-economic status, where higher values reflect greater household wealth.

HFIAS refers to the Household Food Insecurity Access Scale, a proxy indicator of household food insecurity, based on Coates et al. (2007).

Abbreviations: HACS, Household Asset Composite Score; HFIAS, Household Food Insecurity Access Scale.



Household factors as effect modifiers of the association between NIHM's perception or acceptance and endline spot UIC of WRA in the CoMIT project

Table 7.13 summarises the interaction effects of household factors on the relationship between NIHM's perception or acceptance scores and endline spot UIC in WRA across study groups.

At T1, perception showed a statistically significant interaction with the sex of the household head (EDF = 3.54; $F = 3.49$; $p = 0.010$). Subgroup analyses (**Table 7.14**) showed that this interaction was significant among male-headed households (EDF = 3.58; $F = 3.86$; $p = 0.004$) but not among female-headed households ($p = 0.74$). The educational level of the household head showed an initially significant interaction with perception during screening (EDF = 1.00; $F = 3.33$; $p = 0.069$). Subgroup analysis indicated a statistically significant interaction in households where the head had no formal education (EDF = 3.30; $F = 4.60$; $p = 0.002$), but not at other education levels.

Acceptance at T1 showed a significant interaction with the sex of the household head (EDF = 3.30; $F = 2.94$; $p = 0.018$). Subgroup analysis indicated significant in male-headed households (EDF = 3.26; $F = 2.87$; $p = 0.025$), but not in female-headed households ($p = 0.20$).

At T2, perception showed a significant interaction with household food insecurity (EDF = 1.00; $F = 3.96$; $p = 0.047$). Subgroup analysis indicated a significant effect in food-secure households (EDF = 2.93; $F = 4.04$; $p = 0.021$), with no significant interactions observed in mildly, moderately, or severely food-insecure households.

Acceptance at T2 also showed a significant interaction with household food insecurity (EDF = 4.02; $F = 3.09$; $p = 0.022$). Subgroup analysis showed a statistically

significant effect in moderately food-insecure households (EDF = 1.00; $F = 20.33$; $p < 0.001$), while no significant interactions were observed in other food insecurity categories.

Other household-level characteristics, including the number of household members, household baseline bouillon consumption (g/capita/day), and the socio-economic status, did not show statistically significant interactions with either perception or acceptance at T1 or T2.



Table 7.13. Household-level factors as effect modifiers of the association between non-index household members' perception or acceptance scores and endline spot urinary iodine concentration in women of reproductive age from the CoMIT project

Variables	EDF ¹	F-value	P-value
<i>Perception at T1: Interaction Effects</i>			
Educational level of household head	1.00	3.33	0.069*
Household size	1.00	1.37	0.242
Household bouillon consumption (g/capita/day)	1.00	1.98	0.160
HFIAS	1.66	0.65	0.557
HACS	1.89	0.84	0.454
Sex of household head	3.54	3.49	0.010*
<i>Acceptance at T1: Interaction Effects</i>			
Educational level of household head	1.21	0.15	0.664
Household size	1.00	0.08	0.775
Household bouillon consumption (g/capita/day)	1.00	0.81	0.368
HFIAS	1.00	0.83	0.361
HACS	1.00	1.50	0.188
Sex of Household head	3.30	2.94	0.018*
<i>Perception at T2: Interaction Effects</i>			
Educational level of household head	1.00	1.46	0.227
Household size	1.00	0.12	0.734
Household bouillon consumption (g/capita/day)	2.08	2.72	0.124
HFIAS	1.00	3.96	0.047*
HACS	1.00	0.14	0.711
Sex of the household head	1.00	2.19	0.139
<i>Acceptance at T2: Interaction Effects</i>			
Educational level of household head	1.00	0.03	0.869
Household Size	1.00	0.21	0.644
Household bouillon consumption (g/capita/day)	1.00	0.00	0.999
HFIAS	4.02	3.09	0.022*
HACS	2.46	1.49	0.243
Sex of household head	1.63	1.85	0.160

Note:

¹EDF (Effective Degrees of Freedom) reflects the complexity of the association, where an EDF of 1 indicates a linear relationship, and an EDF greater than 1 indicates a non-linear association.

P-values indicate the significance level for the smooth term or interaction effect. Significant terms were defined as $p < 0.1$ for categorical variables and $p < 0.05$ for continuous variables and are marked with an asterisk (*).

HACS refers to the Household Asset Composite Score, a proxy indicator of household socio-economic status, where higher values reflect greater wealth.

HFIAS refers to the Household Food Insecurity Access Scale, a validated proxy for food insecurity, categorised as food secure, mildly insecure, moderately insecure, and severely insecure (Coates et al., 2007).

All models included household-level factors as main effects. Covariates adjusted for in each model included baseline urinary iodine concentration (UIC), age, educational level, and marital status of women of reproductive age (WRA), as well as the age and sex of non-index household members.

Analysis was conducted using Generalised Additive Mixed Models.

Abbreviations: EDF, effective degrees of freedom; HACs, Household Asset Composite Score; HFIAS, Household Food Insecurity Access Scale.

Table 7.14. Subgroup analysis of the modification effects of household-level factors on the association between non-index household members' perception or acceptance scores and endline spot urinary iodine concentration in women of reproductive age from the CoMIT project

Variables	EDF ¹	F-value	P-value
<i>Perception at T1: Interaction Effects</i>			
Household head sex = <i>Male</i>	3.58	3.86	0.004*
Household head sex = <i>Female</i>	1.00	0.18	0.740
Household head education = <i>No formal education</i>	3.30	4.60	0.002*
Household head education = <i>Basic education</i>	1.00	0.01	0.948
Household head education = <i>SHS and Higher</i>	1.00	0.02	0.949
<i>Acceptance at T1: Interaction Effects</i>			
Household head sex = <i>Male</i>	3.26	2.87	0.025*
Household head sex = <i>Female</i>	1.64	3.62	0.198
<i>Acceptance_T2: Interaction Effects</i>			
Household food insecurity = <i>Food secure</i>	1.12	3.72	0.064
Household food insecurity = <i>mildly food insecure</i>	1.00	1.28	0.270
Household food insecurity = <i>moderately food insecure</i>	1.00	20.33	<0.001*
Household food insecurity = <i>Severely food insecure</i>	3.34	3.30	0.059
<i>Perception at T2: Interaction Effects</i>			
Household food insecurity = <i>Food secure</i>	2.93	4.04	0.021 *
Household food insecurity = <i>mildly food insecure</i>	1.00	1.28	0.270
Household food insecurity = <i>moderately food insecure</i>	2.93	2.33	0.066
Household food insecurity = <i>Severely food insecure</i>	1.37	0.50	0.448

Note:

EDF (Effective Degrees of Freedom) indicates the complexity of the association, where an EDF of 1 represents a linear association and an EDF greater than 1 represents a non-linear association.

P-values were derived from Generalised Additive Mixed Models used in subgroup analysis. A $p < 0.05$ was considered statistically significant and is marked with an asterisk (*).

Discussion

This study examined whether perceptions and acceptance of micronutrient-fortified bouillon cubes among non-index household members (NIHMs) were associated with haemoglobin (Hb) and urinary iodine concentration (UIC) in preschool children (PSC) and women of reproductive age (WRA), and whether these relationships were modified by household characteristics using data from the CoMIT randomised trial in northern Ghana.

No significant associations were observed between perception or acceptance and Hb concentrations in the overall samples of PSC or WRA. However, household factors modified these associations. Among PSC, both perception and acceptance interacted with the household head's age (inverse) and household baseline bouillon-cube use (positive). In WRA, acceptance interacted with household-head age (inverse at T1, positive at T2), socio-economic status (positive), and household size (inverse); perception interacted positively with socio-economic status and baseline bouillon-cube use. These patterns indicate that the behavioural–nutritional relationship was not uniform across households. Younger household heads and greater household baseline bouillon-cube use appeared to amplify the nutritional impact.

For iodine status, distinct non-linear and linear associations emerged. Among PSC, early perceptions were linked to endline UIC in a non-linear form, while acceptance showed a linear association, strongest in male-headed and better-educated households. At the later time point, only acceptance remained significant. In WRA, both perception and acceptance were associated with endline UIC across time points, following non-linear trends. Sub-group analyses revealed stronger effects in male-headed and low-education households, and interactions with food-security, with perception linked to food-secure and

acceptance to moderately food-insecure households. Collectively, positive household perceptions and sustained acceptance were associated with improved iodine status, though the magnitude varied by household demographics and food-security conditions.

Consistent with findings from Abizari et al. (2017), the strong link between favourable perceptions and iodine status reinforces the role of bouillon cubes as practical iodine-delivery vehicles in Ghanaian diets (Abizari, Dold, et al., 2017). Similar modelling studies in Ghana, Cameroon, Senegal, and Burkina Faso indicates that bouillon fortification can substantially reduce micronutrient inadequacies due to its near-universal consumption (Engle-Stone, Kumordzie, et al., 2024; Thompson et al., 2024). These findings collectively confirm that condiment fortification, when socially accepted, can meaningfully contribute to reducing iodine and other micronutrient gaps in West African diets. In contrast, the null Hb association aligns with previous fortification trials showing limited haemoglobin responses to condiment-based interventions (Dold et al., 2020; Hurrell & Egli, 2010; Waller et al., 2020). This suggests that behavioural adoption alone may not translate into measurable iron improvements because of biological and contextual constraints.

This study's strength lies in the use of validated instruments derived through factor analysis (EFA and CFA) to quantify composite scores for perceptions and acceptance (DiStefano et al., 2009; Hair Jr et al., 2020). Advanced statistical approaches, generalised estimated equations and generalised additive mixed models, enabled rigorous analysis of both linear and non-linear associations and modifications (Li & Kong, 2023; Liang & Zeger, 1986). These techniques enabled precise interpretation of complex behavioural–nutritional dynamics and outperformed simpler models that may overlook non-linear

associations (Li & Kong, 2023). Importantly, this is the first study to quantitatively assess how NIHMs' perceptions and acceptance relate to Hb and UIC outcomes in household fortification interventions in sub-Saharan Africa. The analysis was conducted within a randomised controlled trial evaluating micronutrient-fortified bouillon cubes. The examination of household-level modifiers, including food-insecurity, household head demographics, and household baseline bouillon cube consumption, further deepened understanding of the behavioural and contextual determinants influencing nutritional outcomes. The use of a large, representative sample across diverse rural and peri-urban clusters in northern Ghana enhances both internal and contextual validity.

Limitations include reliance on self-reported perception and acceptance data, which may introduce recall and social-desirability bias (Bradburn et al., 1987; Durmaz et al., 2020). Additionally, the nine-month intervention period may have been insufficient to capture long-term or cumulative effects. Findings may not generalise beyond northern Ghana's dietary and sociocultural context.

The study's observed pattern of strong UIC but weak Hb responses aligns with behavioural theories explaining adoption variability. This theoretical framing helps explain why adoption patterns varied across households and why improvements in iodine but not iron status was observed. According to Rogers' Diffusion of Innovations and the Theory of Planned Behaviour (Ajzen, 1991; Rogers, 2003), social norms, perceived control, and education shape sustained product use. For example, education influences comprehension and control over food decisions (Azizi Fard et al., 2021; Sari et al., 2024). Similarly, the sex of the household head may shape social expectations and roles in food provision, influencing both perceived behavioural control and adherence to the nutrition interventions

(Gligorić et al., 2024; Gupta, 2025). Integrating additional behavioural models further strengthens this interpretation. The Social Cognitive Theory (Bandura, 1986) emphasises self-efficacy and observational learning, while the Health Belief Model (Rosenstock, 1974) highlights the influence of perceived barriers and benefits on health behaviours. Together, these theories clarify how self-efficacy, perceived obstacles, and the social context shape household behaviour concerning the fortified bouillon cube usage (Ajzen, 1991; Bandura, 1986). These understandings reinforce the importance of adapting interventions to specific population subgroups. Comparable interventions in West Africa have reported similar behaviour–context interactions, confirming that household-targeted communication strategies enhance the sustained use of fortified products (Bhutta et al., 2013; Ruel & Alderman, 2013).

The nutrient-specific outcomes indicate that the fortified bouillon cube effectively improved iodine intake but not iron status. The latter may reflect limited iron absorption because bouillon cubes are consumed with cereal- and legume-based meals rich in phytates and polyphenols, as well as infection-related inflammation common in northern Ghana (Hurrell & Egli, 2010; Wegmüller et al., 2020). These factors can restrict non-haem-iron utilisation even when intake is adequate.

Additionally, the study found that food-insecurity and baseline household bouillon-cube consumption also modified the associations, consistent with evidence that socio-economically constrained households depend more on fortified foods to supplement nutrient intake (Olson et al., 2021; Placzek, 2021; Pourebrahim et al., 2024). Such contextual effects underscore the need to design fortification strategies that reflect household realities.

Maintaining iodine benefits requires a stable supply chain and appropriate storage and cooking to prevent iodine loss (Dary & Hurrell, 2006; Zimmermann & Andersson, 2012). In addition, ensuring access for food-insecure households may require equity-focused measures such as subsidies or vouchers (Horton & Mannar, 2018). Programmes should therefore integrate behavioural, biological, and policy strategies to strengthen fortification impact.

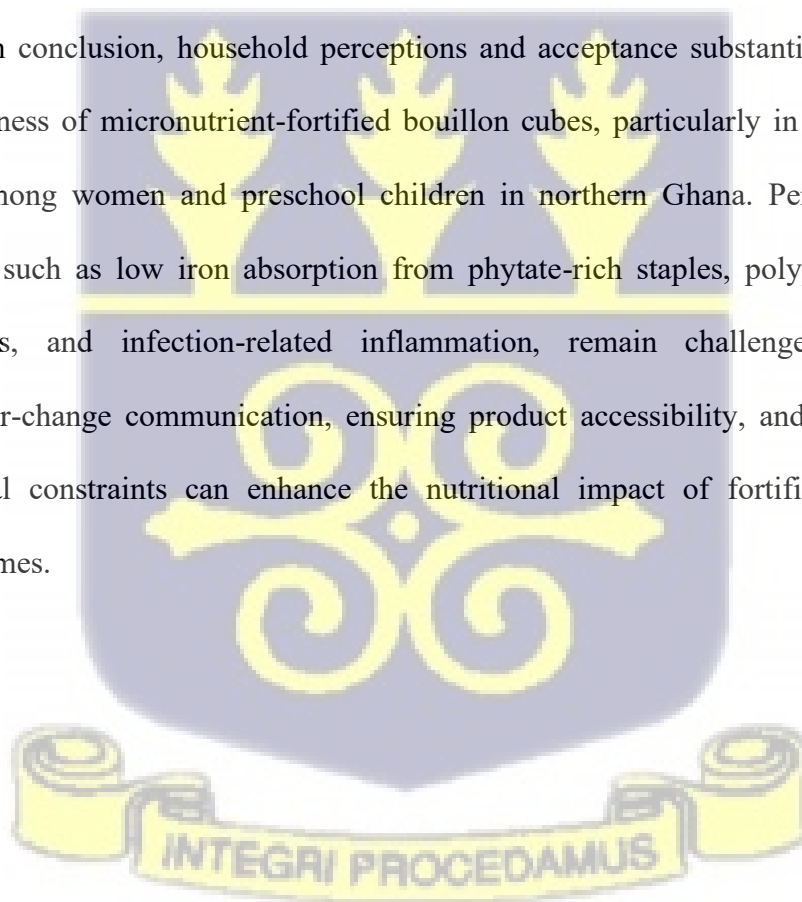
The current study highlights the importance of context-sensitive interventions that integrate socio-economic and cultural dimensions into fortification programme design. From a global public health perspective, these findings support fortification programmes that respond to local contexts. Integrating these results into policy could promote multisectoral approaches to addressing MNDs in West Africa (Bhutta et al., 2013).

This study links household behavioural constructs with objective micronutrient biomarkers within a fortification-trial framework, addressing a major research gap: the lack of quantitative evidence connecting social and behavioural determinants of fortified-bouillon-cube acceptance to measurable nutritional outcomes. Previous research largely emphasised product efficacy or coverage, but these findings extend that evidence by revealing how household dynamics, perception, and acceptance modify biological responses. This integrative behavioural–nutritional analysis fills a critical gap and provides a model for future fortification research in Ghana and other sub-Saharan African countries.

Future research should extend intervention duration to capture longer-term behavioural and nutritional effects; combine quantitative and qualitative methods to examine household decision processes; and broaden biomarker assessment to ferritin, retinol-binding protein, zinc, and inflammatory markers. Testing reformulated products

that combine iron with iodine, while addressing infections and inherited haemoglobin disorders, will clarify whether integrated fortification can reduce multifactorial anaemia (Dold et al., 2020; Ramírez-Luzuriaga et al., 2018; Reddy et al., 2022). Community-based education, especially in low-education, food-insecure settings, should promote understanding of micronutrient benefits through participatory approaches (Bhutta et al., 2013; Norris et al., 2023). Finally, mechanistic and cost-effectiveness studies are needed to better understand the biological and behavioural pathways influencing household-level outcomes. These efforts would inform policy decisions for scaling up micronutrient-fortified bouillon cube programmes in West Africa (Jadhav et al., 2019).

In conclusion, household perceptions and acceptance substantially influence the effectiveness of micronutrient-fortified bouillon cubes, particularly in improving iodine status among women and preschool children in northern Ghana. Persistent biological barriers, such as low iron absorption from phytate-rich staples, polyphenol-containing beverages, and infection-related inflammation, remain challenges. Strengthening behaviour-change communication, ensuring product accessibility, and addressing these biological constraints can enhance the nutritional impact of fortified bouillon cube programmes.



PART FOUR: DISCUSSION AND CONCLUSION

CHAPTER EIGHT

SUMMARY OF DISCUSSION AND CONCLUSION

8.1 DISCUSSION OF FINDINGS

This study investigated how NIHMs' perceptions and acceptance of micronutrient-fortified bouillon cubes influenced the effectiveness of fortification interventions. Using a mixed-methods approach embedded in a randomised trial in northern Ghana, the research developed and validated a culturally grounded measurement tool, examined longitudinal changes in perception and acceptance, and explored their associations with nutritional outcomes.

A major contribution of this work is the development of a novel, culturally adapted tool for measuring perception and acceptance, guided by behavioural theory (the TPB and the HBM). The emergence of two empirically distinct constructs provided a strong foundation for subsequent analyses. Longitudinal application of the tool showed that perception scores improved over time, influenced by sensory qualities, health beliefs, and trust, while acceptance scores remained consistently high. This suggests a potential ceiling effect in micronutrient uptake, with early adoption followed by more gradual refinement of attitudes.

While perception and acceptance were not significantly associated with haemoglobin concentration, they showed significant associations with urinary iodine concentration, particularly in households characterised by food insecurity, low formal educational attainment, and male heads. These findings reflect the modifying effects of household context on intervention outcomes.

The integration of qualitative and quantitative data added further depth, revealing that sensory appeal, cultural compatibility, and affordability strongly influenced acceptance. However, concerns about long-term health effects and changes in food appearance persisted among some participants, highlighting the need for sustained and targeted communication efforts.

Overall, this study supports an integrated framework for fortification interventions that combines behavioural, cultural, and contextual considerations. The findings emphasise the importance of continuous behavioural monitoring and responsive programme design to enhance the impact and sustainability of micronutrient interventions.

8.1.1 STRENGTHS OF THE STUDY

1. A novel questionnaire was developed and validated through rigorous exploratory and confirmatory factor analyses. This tool addresses an important gap in assessing perception and acceptance of fortified bouillon cubes in low-resource settings and offers broader applicability for evaluating similar interventions.
2. The study employed a comprehensive mixed-methods design, combining quantitative surveys and focus group discussions nested within a double-blinded randomised controlled trial. Bayesian linear mixed-effects models were used to capture longitudinal changes in perception and acceptance.
3. The use of GEEs and GAMMs provided a robust analytical framework for examining the relationships between household behavioural responses and nutritional outcomes, particularly urinary iodine concentration.

4. This is the first study to quantitatively link household perception and acceptance among non-index household members to haemoglobin and iodine status in women and children within a randomised trial of micronutrient-fortified bouillon cubes.
5. The theoretical foundation based on the TPB and HBM strengthened the conceptual design and interpretation of findings, offering a transferable framework for context-relevant nutrition programming.

8.1.2 WEAKNESSES OF THE STUDY

Despite its strong design and valuable contributions, the study has some limitations that should be considered:

1. Although NIHMs' perceptions and acceptance were measured using a culturally adapted and validated instrument, the use of self-reported data introduces the possibility of social desirability and recall bias. These may affect the accuracy of responses and the precision of the findings.
2. The study focused on a specific cultural group (Dagomba) within a predominantly Islamic setting and excluded households that did not use bouillon cubes. These factors may limit the generalisability of the findings to other populations or regions with different cultural or dietary practices.
3. As the analysis was limited to haemoglobin and urinary iodine concentrations, the study did not capture other potential nutritional outcomes, such as zinc, vitamin A, or folate status, nor did it include inflammatory markers that could contextualise these results.

8.2 CONCLUSIONS

This study strengthens understanding of how household perceptions and acceptance influence the success of micronutrient-fortification interventions. The validated questionnaire developed under Objective 1 provides a contextually relevant tool for assessing household perceptions and acceptance within northern Ghana. Its broader applicability and effectiveness in other settings warrant further evaluation in future studies.

Findings from Objective 2 showed that perceptions of the fortified bouillon cubes changed over time, while acceptance remained high throughout the intervention. Sensory appeal, perceived health benefits, cultural familiarity, economic relief, and trust shaped these responses. However, the early strong acceptance may have reached a ceiling, suggesting the need for continued engagement to sustain interest and regular use.

Under Objective 3, positive perceptions and sustained acceptance were linked to improved iodine status in PSC and WRA, while no association was found with Hb concentrations. Further studies are required to explore factors influencing iron status.

The study also found that household characteristics such as food security, household size, and the education level of the household head influenced perception and acceptance. These findings support the need for fortified food programmes that consider affordability, access, and cultural preferences, as well as household dynamics.

Overall, the results contribute to global efforts to reduce micronutrient deficiencies and align with Sustainable Development Goals (SDGs) 2 and 3. Future research should examine how fortification programmes can be integrated into national health systems and whether strategies such as dietary diversification or combining nutrients with absorption enhancers can improve their long-term impact.

8.3 RECOMMENDATIONS

The study provides eleven main recommendations, categorised under two themes, as follows:

Policy and practice

- 1. Scale up access and integration into public programmes:** Efforts should be made to expand the production and equitable distribution of micronutrient-fortified bouillon cubes across Ghana and the wider West African region. Policymakers are encouraged to promote affordability through targeted subsidies and to integrate fortified bouillon cubes into existing public health and nutrition interventions, such as school feeding and maternal and child nutrition programmes. Such integration can enhance programme reach and encourage sustained adoption, particularly among vulnerable populations.
- 2. Strengthen community engagement through culturally responsive communication:** Promote trust and informed use by designing locally adapted communication strategies that reflect community values, address specific misconceptions, and highlight the nutritional benefits of fortified cubes. Engagement should involve participatory approaches, including local leaders and trusted voices, to foster relevance, credibility, and behavioural reinforcement.
- 3. Enhance regulatory and quality-assurance systems:** Establish and enforce strong regulatory frameworks to ensure product safety, consistency, and consumer protection. Coordination among government agencies, non-governmental organisations, and private-sector actors is essential for effective monitoring,

standard-setting, and compliance. Strong regulatory oversight also builds consumer confidence and supports market sustainability.

4. **Incorporate behavioural tracking into monitoring systems:** Integrate validated tools that measure perception and acceptance into routine monitoring and evaluation of fortification programmes. This behavioural dimension provides early signals of uptake challenges and helps guide responsive programme adjustment during roll-out.

Addressing concerns about bouillon fortification

5. **Clarify health-related misconceptions and salt reduction concerns:** Long-standing policy concerns regarding the sodium content of bouillon cubes have contributed to hesitancy in adopting them as a fortification vehicle. Public-health communication should emphasise that fortification can align with salt-reduction efforts through reformulation, portion control, and public awareness. Messaging should transparently address this balance, consistent with international guidance, including that from the World Health Organization.
6. **Ensure transparency in fortification levels and voluntary use:** A common concern has been the variability in household usage patterns and serving sizes of bouillon cubes. To address this, fortification levels should be standardised across brands, with transparent labelling that allows for informed consumer choice. Maintaining the voluntary nature of consumption and promoting consumer awareness will help address ethical concerns while supporting effective micronutrient delivery.

7. **Strengthen industry partnerships for sustainable fortification:** Food-manufacturing industries, particularly bouillon producers, should work with government and research institutions to improve product formulations that balance taste, salt reduction, and micronutrient delivery. Industry involvement is needed in reformulating products with bioavailable fortificants (e.g. NaFeEDTA), adopting uniform fortification standards, and supporting public education through clear labelling and responsible marketing. Financial or recognition incentives can promote compliance and innovation. Aligning public-health goals with market interests will help scale up fortification and ensure long-term sustainability.

Future research

8. **Support longitudinal studies on behavioural and health outcomes:** Future studies should adopt longitudinal designs to investigate how perceptions and acceptance of fortified bouillon cubes evolve over time and how these changes influence sustained usage. Such research should also explore how these behavioural factors relate to nutritional outcomes across different household and community settings.
9. **Expand nutritional biomarker coverage and dietary-context assessment:** Future evaluations should include a broader range of biochemical indicators, such as vitamin A, vitamin B₁₂, zinc, and folate, along with contextual dietary-intake data. This will provide a more comprehensive understanding of the biological pathways and the real-world nutritional impact of fortified foods.
10. **Evaluate cost-effectiveness to guide scale-up:** Undertake cost-effectiveness analyses to assess the financial feasibility and resource implications of expanding

fortified-bouillon-cube programmes. These findings are critical for policymakers and donors to allocate funds efficiently, especially in low-income settings.

11. **Use objective and mixed methods approaches:** Future research should combine objective indicators, such as biochemical measures and standardised survey tools, with qualitative methods that explore contextual factors influencing use. Incorporating measurement-invariance testing across diverse sub-populations will enhance comparability and the generalisability of findings. Triangulating multiple data sources will improve the reliability and credibility of conclusions drawn.



REFERENCE

- Abizari, A.-R., Azupogo, F., Nagasu, M., Creemers, N., & Brouwer, I. D. (2017). Seasonality affects dietary diversity of school-age children in northern Ghana. *PloS one*, 12(8), e0183206.
- Abizari, A.-R., Dold, S., Kupka, R., & Zimmermann, M. B. (2017). More than two-thirds of dietary iodine in children in northern Ghana is obtained from bouillon cubes containing iodized salt. *Public Health Nutrition*, 20(6), 1107-1113.
- Abu, B. A., Oldewage-Theron, W., & Aryeetey, R. N. (2019). Risks of excess iodine intake in Ghana: current situation, challenges, and lessons for the future. *Annals of the new York Academy of Sciences*, 1446(1), 117-138.
- Abu, B. A. Z., Raubenheimer, J. E., & Van Den Berg, V. L. (2020). Iron-focussed nutritional status of mothers with children (6–59 months) in rural northern Ghana. *Heliyon*, 6(6).
- Adams, K. P., Okronipa, H., Adu-Afarwuah, S., Arimond, M., Kumordzie, S., Oaks, B. M., Ocansey, M. E., Young, R. R., Vosti, S. A., & Dewey, K. G. (2018). Ghanaian parents' perceptions of pre and postnatal nutrient supplements and their effects. *Maternal & child nutrition*, 14(4), e12608.
- Adams, K. P., Vosti, S. A., Somé, J. W., Tarini, A., Becher, E., Koudougou, K., & Engle-Stone, R. (2024). Micronutrient-fortified bouillon as a strategy to improve the micronutrient adequacy of diets in Burkina Faso. *Annals of the new York Academy of Sciences*.
- Adams., Vosti, S. A., Tarini, A., Beye, M., Pachón, H., Kiselova, S., & Engle-Stone, R. (2024). The potential contributions of bouillon fortification to meeting micronutrient requirements among women and preschool children in Senegal: A modeling study using household consumption and expenditure survey data. *Ann N Y Acad Sci*, 1537(1), 98-112. <https://doi.org/10.1111/nyas.15156>
- Adu-Afarwuah, S., Lartey, A., Brown, K. H., Zlotkin, S., Briend, A., & Dewey, K. G. (2008). Home fortification of complementary foods with micronutrient supplements is well accepted and has positive effects on infant iron status in Ghana. *The American journal of clinical nutrition*, 87(4), 929-938.
- Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, 50(2), 179-211.
- Akhtar-Danesh, N. (2023). Impact of factor rotation on Q-methodology analysis. *PloS one*, 18(9), e0290728.
- Alavi, M., Visentin, D. C., Thapa, D. K., Hunt, G. E., Watson, R., & Cleary, M. (2020a). Chi-square for model fit in confirmatory factor analysis. *Journal of advanced nursing*, 76(9), 2209-2211.
- Alavi, M., Visentin, D. C., Thapa, D. K., Hunt, G. E., Watson, R., & Cleary, M. (2020b). Exploratory factor analysis and principal component analysis in clinical studies: Which one should you use. *Journal of advanced nursing*, 76(8), 1886-1889.
- Allen, L. (2006). *Guidelines on food fortification with Micronutrients*. Citeseer.
- Anuar, H., Shah, S., Gafor, H., Mahmood, M., & Ghazi, H. F. (2020). Usage of Health Belief Model (HBM) in health behavior: A systematic review. *Malaysian Journal of Medicine and Health Sciences*, 16(11), 2636-9346.
- Archer, N. S., Cochet-Broch, M., Mihnea, M., Garrido-Bañuelos, G., Lopez-Sanchez, P., Lundin, L., & Frank, D. (2022). Sodium Reduction in Bouillon: Targeting a Food

- Staple to Reduce Hypertension in Sub-saharan Africa. *Front Nutr*, 9, 746018. <https://doi.org/10.3389/fnut.2022.746018>
- Austin, P. C., Kapral, M. K., Vyas, M. V., Fang, J., & Yu, A. Y. X. (2024). Using Multilevel Models and Generalized Estimating Equation Models to Account for Clustering in Neurology Clinical Research. *Neurology*, 103(9), e209947. <https://doi.org/10.1212/wnl.00000000000209947>
- Azizi Fard, N., De Francisci Morales, G., Mejova, Y., & Schifanella, R. (2021). On the interplay between educational attainment and nutrition: a spatially-aware perspective. *EPJ Data Science*, 10(1), 18. <https://doi.org/10.1140/epjds/s13688-021-00273-y>
- Azupogo, F., Abizari, A.-R., Feskens, E. J., Verhoef, H., & Brouwer, I. D. (2024). Ten2Twenty-Ghana: a randomised controlled trial on the efficacy of multiple micronutrient-fortified biscuits on the micronutrient status of adolescent girls. *British Journal of Nutrition*, 131(4), 707-719.
- Bailey, R. L., West Jr, K. P., & Black, R. E. (2015). The epidemiology of global micronutrient deficiencies. *Annals of nutrition and metabolism*, 66(Suppl. 2), 22-33.
- Baker, M. T., Lu, P., Parrella, J. A., & Leggette, H. R. (2022). Consumer Acceptance toward Functional Foods: A Scoping Review. *Int J Environ Res Public Health*, 19(3). <https://doi.org/10.3390/ijerph19031217>
- Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, 1986(23-28), 2.
- Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, 25(24), 3186-3191.
- Bechoff, A., Chijioke, U., Westby, A., & Tomlins, K. I. (2018). ‘Yellow is good for you’: consumer perception and acceptability of fortified and biofortified cassava products. *PloS one*, 13(9), e0203421.
- Bechoff, A., de Bruyn, J., Alpha, A., Wieringa, F., & Greffeuille, V. (2023). Exploring the Complementarity of Fortification and Dietary Diversification to Combat Micronutrient Deficiencies: A Scoping Review. *Curr Dev Nutr*, 7(2), 100033. <https://doi.org/10.1016/j.cdnut.2023.100033>
- Beressa, G., Whiting, S. J., & Belachew, T. (2024). Effect of nutrition education integrating the health belief model and theory of planned behavior on dietary diversity of pregnant women in Southeast Ethiopia: a cluster randomized controlled trial. *Nutrition Journal*, 23(1), 3. <https://doi.org/10.1186/s12937-023-00907-z>
- Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., Webb, P., Lartey, A., & Black, R. E. (2013). Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet*, 382(9890), 452-477. [https://doi.org/10.1016/s0140-6736\(13\)60996-4](https://doi.org/10.1016/s0140-6736(13)60996-4)
- Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., & Martorell, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The lancet*, 382(9890), 427-451.
- Blei, D., Ng, A., & Jordan, M. (2003). Latent Dirichlet Allocation. *Journal of Machine Learning Research*, 3.

- Boatema, S., Badasu, D. M., & de-Graft Aikins, A. (2018). Food beliefs and practices in urban poor communities in Accra: implications for health interventions. *BMC Public Health*, 18, 1-12.
- Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quinonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: a primer. *Frontiers in Public Health*, 6, 149.
- Bradburn, N. M., Rips, L. J., & Shevell, S. K. (1987). Answering autobiographical questions: The impact of memory and inference on surveys. *Science*, 236(4798), 157-161.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.
- Braun, V., & Clarke, V. (2021). Thematic analysis: A practical guide.
- Brown, K. H., Rivera, J. A., Bhutta, Z., Gibson, R. S., King, J. C., Lönnerdal, B., Ruel, M. T., Sandtröm, B., Wasantwisut, E., & Hotz, C. (2004). International Zinc Nutrition Consultative Group (IZiNCG) technical document #1. Assessment of the risk of zinc deficiency in populations and options for its control. *Food Nutr Bull*, 25(1 Suppl 2), S99-203.
- Brown, T. A. (2015). *Confirmatory factor analysis for applied research*. Guilford publications.
- Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of statistical software*, 80, 1-28.
- Bürkner, P.-C. (2021). Bayesian item response modeling in R with brms and Stan. *Journal of statistical software*, 100, 1-54.
- Byrne, B. M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. routledge.
- Calvo-Porral, C., Rivaroli, S., & Orosa-González, J. (2024). Proposal and validation of a measurement scale of the acceptance of ultra-processed food products. *Foods*, 13(10), 1481.
- Caso, D., Canova, L., Capasso, M., & Bianchi, M. (2024). Integrating the theory of planned behavior and the self-determination theory to promote Mediterranean diet adherence: A randomized controlled trial. *Applied Psychology: Health and Well-Being*, 16(1), 80-101.
- Chadare, F. J., Idohou, R., Nago, E., Affonfere, M., Agossadou, J., Fassinou, T. K., Kénou, C., Honfo, S., Azokpota, P., & Linnemann, A. R. (2019). Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. *Food Science & Nutrition*, 7(9), 2781-2795.
- Chai, C. P. (2023). Comparison of text preprocessing methods. *Natural Language Engineering*, 29(3), 509-553.
- Chakona, G., & Shackleton, C. (2019). Food taboos and cultural beliefs influence food choice and dietary preferences among pregnant women in the Eastern Cape, South Africa. *Nutrients*, 11(11), 2668.
- Chauhan, U., & Shah, A. (2021). Topic modeling using latent Dirichlet allocation: A survey. *ACM Computing Surveys (CSUR)*, 54(7), 1-35.
- Chen, D.-G., Lio, Y., & Wilson, J. R. (2022). Bayesian Approach for Joint Modeling Longitudinal Data and Survival Data Simultaneously in Public Health Studies. In Y. Lio, D.-G. Chen, H. K. T. Ng, & T.-R. Tsai (Eds.), *Bayesian Inference and*

- Computation in Reliability and Survival Analysis* (pp. 343-355). Springer International Publishing. https://doi.org/10.1007/978-3-030-88658-5_16
- Chen, N.-C., Drouhard, M., Kocielnik, R., Suh, J., & Aragon, C. R. (2018). Using machine learning to support qualitative coding in social science: Shifting the focus to ambiguity. *ACM Transactions on Interactive Intelligent Systems (TiiS)*, 8(2), 1-20.
- Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2024). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. *Asia Pacific Journal of Management*, 41(2), 745-783.
- Chowdhury, M. Z. I., & Turin, T. C. (2020). Variable selection strategies and its importance in clinical prediction modelling. *Fam Med Community Health*, 8(1), e000262. <https://doi.org/10.1136/fmch-2019-000262>
- Christian, A. K., & Dake, F. A. (2022). Profiling household double and triple burden of malnutrition in sub-Saharan Africa: prevalence and influencing household factors. *Public Health Nutrition*, 25(6), 1563-1576.
- Christian, A. K., Marquis, G. S., Colecraft, E. K., Lartey, A., Sakyi-Dawson, O., Ahunu, B. K., & Butler, L. M. (2016). Caregivers' nutrition knowledge and attitudes are associated with household food diversity and children's animal source food intake across different agro-ecological zones in Ghana. *British Journal of Nutrition*, 115(2), 351-360.
- Coates, J., Swindale, A., & Bilinsky, P. (2007). Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide: version 3.
- Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. routledge.
- Creed-Kanashiro, H., Bartolini, R., Abad, M., & Arevalo, V. (2016). Promoting multi-micronutrient powders (MNP) in Peru: Acceptance by caregivers and role of health personnel. *Maternal & child nutrition*, 12(1), 152-163.
- Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Dary, O., & Hurrell, R. (2006). Guidelines on food fortification with micronutrients. *World Health Organization, Food and Agricultural Organization of the United Nations: Geneva, Switzerland, 2006*, 1-376.
- Das, J. K., Salam, R. A., Mahmood, S. B., Moin, A., Kumar, R., Mukhtar, K., Lassi, Z. S., & Bhutta, Z. A. (2019). Food fortification with multiple micronutrients: impact on health outcomes in general population. *Cochrane Database Syst Rev*, 12(12), Cd011400. <https://doi.org/10.1002/14651858.CD011400.pub2>
- Davis, J. N., Kumordzie, S. M., Arnold, C. D., Wessells, K. R., Nyaaba, K. W., Adams, K. P., Tan, X. J., Becher, E., Vosti, S. A., & Adu-Afarwuah, S. (2024). Consumption of discretionary salt and salt from bouillon among households, women, and young children in Northern Region, Ghana: A mixed-methods study with the condiment micronutrient innovation trial (CoMIT) project. *Current Developments in Nutrition*, 8(3), 102088.
- de Barros, S. F., & Cardoso, M. A. (2016). Adherence to and acceptability of home fortification with vitamins and minerals in children aged 6 to 23 months: a systematic review. *BMC Public Health*, 16, 1-11.

- De Groote, H., Mugalavai, V., Ferruzzi, M., Onkware, A., Ayua, E., Duodu, K. G., Ndegwa, M., & Hamaker, B. R. (2020). Consumer acceptance and willingness to pay for instant cereal products with food-to-food fortification in Eldoret, Kenya. *Food and nutrition bulletin*, 41(2), 224-243.
- De Vet, H. C., Terwee, C. B., Mokkink, L. B., & Knol, D. L. (2011). *Measurement in medicine: a practical guide*. Cambridge university press.
- Dembedza, M. P., Chopera, P., & Matsungu, T. M. (2023). Risk of zinc deficiency among children aged 0–59 months in sub-Saharan Africa: a narrative review. *South African Journal of Clinical Nutrition*, 1-8.
- DeVellis, R. F., & Thorpe, C. T. (2021). *Scale development: Theory and applications*. Sage publications.
- DiStefano, C., Zhu, M., & Mindrila, D. (2009). Understanding and using factor scores: Considerations for the applied researcher. *Practical assessment, research, and evaluation*, 14(1).
- Dold, S., Zimmermann, M. B., Jeroense, F., Zeder, C., Habeych, E., Galaffu, N., Grathwohl, D., Tajeri Foman, J., Merinat, S., & Rey, B. (2020). Iron bioavailability from bouillon fortified with a novel ferric phytate compound: a stable iron isotope study in healthy women (part II). *Scientific reports*, 10(1), 5339.
- Duggal, M., Sesikeran, B., Arlappa, N., Nair, S., Shekhar, V., & Sabharwal, V. (2022). Large-scale staple food fortification as a complementary strategy to address vitamin and mineral vulnerabilities in India: A critical review. *Indian J Public Health*, 66(3), 313-320. https://doi.org/10.4103/ijph.ijph_708_22
- Dunn, T. J., Baguley, T., & Brunson, V. (2014). From alpha to omega: A practical solution to the pervasive problem of internal consistency estimation. *British journal of psychology*, 105(3), 399-412.
- Durmaz, A., Dursun, İ., & Kabadayi, E. T. (2020). Mitigating the effects of social desirability bias in self-report surveys: Classical and new techniques. In *Applied social science approaches to mixed methods research* (pp. 146-185). IGI Global.
- Egbi, G. (2012). Prevalence of vitamin a, zinc, iodine deficiency and anaemia among 2-10 year-old Ghanaian children. *African Journal of Food, Agriculture, Nutrition and Development*, 12(2), 5946-5958.
- Eilander, A., Verbakel, M. R., & Dötsch-Klerk, M. (2023). The Potential of Condiments, Seasonings, and Bouillon Cubes to Deliver Essential Micronutrients in Asia: Scenario Analyses of Iodine and Iron Fortification. *Nutrients*, 15(3), 616.
- Ekoe, T., Bianpam, O. I., Nguefack, F., Pondi, D. M., Kana-Sop, M. M., Hays, N. P., Medoua, G., & Koki, P. N. (2020). Efficacy of an iron-fortified infant cereal to reduce the risk of iron deficiency anemia in young children in East Cameroon. *Food Science & Nutrition*, 8(7), 3566-3577.
- Engle-Stone, R., Adams, K., Kumordzie, S., Luo, H., Wessells, K. R., Adu-Afarwuah, S., Ndjebayi, A., Teta, I., Régis, Y.-L., & Haskell, M. (2021). Analyses using national survey data from Cameroon, Haiti, and Ghana indicate the potential for bouillon fortification to help fill dietary gaps for 5 nutrients. *Current Developments in Nutrition*, 5, 640.
- Engle-Stone, R., Kumordzie, S. M., Luo, H., Wessells, K. R., Adu-Afarwuah, S., Ndjebayi, A., Teta, I., Régis, Y.-L., Gyimah, E., & Vosti, S. A. (2024). The potential for bouillon fortification to reduce dietary micronutrient inadequacy: Modeling

- analyses using national survey data from Cameroon, Ghana, and Haiti. *Current Developments in Nutrition*, 104485.
- Engle-Stone, R., Nankap, M., Ndjebayi, A. O., & Brown, K. H. (2014). Simulations based on representative 24-h recall data predict region-specific differences in adequacy of vitamin A intake among Cameroonian women and young children following large-scale fortification of vegetable oil and other potential food vehicles. *The Journal of nutrition*, 144(11), 1826-1834.
- Engle-Stone, R., Wessells, K. R., Haskell, M. J., Kumordzie, S. M., Arnold, C. D., Davis, J. N., Becher, E. R., Fuseini, A. D., Nyaaba, K. W., & Tan, X. (2023). Effect of household use of multiple micronutrient-fortified bouillon on micronutrient status among women and children in two districts in the Northern Region of Ghana: Protocol for the Condiment Micronutrient Innovation Trial (CoMIT), a community-based randomized controlled trial. *medRxiv*, 2023.2007. 2019.23292899.
- Engle-Stone, R., Wessells, K. R., Haskell, M. J., Kumordzie, S. M., Arnold, C. D., Davis, J. N., Becher, E. R., Fuseini, A. D., Nyaaba, K. W., & Tan, X. (2024). Effect of multiple micronutrient-fortified bouillon on micronutrient status among women and children in the Northern Region of Ghana: Protocol for the Condiment Micronutrient Innovation Trial (CoMIT), a community-based randomized controlled trial. *PloS one*, 19(5), e0302968.
- Essilfie, G., Sebu, J., & Baako-Amponsah, J. (2024). Does Women's Empowerment Matter for Household Food Security? Evidence From Northern Ghana. *Sage Open*, 14(2), 21582440241245076. <https://doi.org/10.1177/21582440241245076>
- Ezezika, O., Gong, J., Abdirahman, H., & Sellen, D. (2021). Barriers and facilitators to the implementation of large-scale nutrition interventions in Africa: a scoping review. *Global Implementation Research and Applications*, 1, 38-52.
- Feinerer, I., Hornik, K., & Meyer, D. (2008). Text Mining Infrastructure in R. *Journal of statistical software*, 25(5), 1 - 54. <https://doi.org/10.18637/jss.v025.i05>
- Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. Sage publications limited.
- Field, K. M., Duncan, A. M., Keller, H. H., Stark, K. D., & Duizer, L. M. (2017). Effect of micronutrient powder addition on sensory properties of foods for older adults. *Journal of Food Science*, 82(10), 2448-2455.
- Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. *Demography*, 38, 115-132.
- Finkelstein, J. L., Cuthbert, A., Weeks, J., Venkatramanan, S., Larvie, D. Y., De-Regil, L. M., & Garcia-Casal, M. N. (2024). Daily oral iron supplementation during pregnancy. *Cochrane database of systematic reviews*(8).
- Fiorentini, M., Kinchla, A. J., & Nolden, A. A. (2020). Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. *Foods*, 9(9), 1334. <https://www.mdpi.com/2304-8158/9/9/1334>
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, 18(1), 39-50.
- Fox, J., & Weisberg, S. (2018). *An R companion to applied regression*. Sage publications.

- Friesen, V. M., Mbuya, M. N., & Neufeld, L. M. (2019). The Fortification Assessment Coverage Toolkit (FACT). *Global Alliance for Improved Nutrition: Geneva, Switzerland*.
- Gabry, J., Simpson, D., Vehtari, A., Betancourt, M., & Gelman, A. (2019). Visualization in Bayesian workflow. *Journal of the Royal Statistical Society Series A: Statistics in Society*, 182(2), 389-402.
- GAIN. (2023a). *GAIN, Mighty Nutrients Coalition Policy Brief: Preventing Micronutrient Deficiencies Worldwide Advocacy Actions to Support WHO's World Health Assembly Resolution on Food Fortification*. Retrieved 10/7/2024 from <https://www.gainhealth.org/sites/default/files/publications/documents/Mighty-Nutrients-Coalition-Policy-Brief-Preventing-Micronutrient-Deficiencies-Worldwide.pdf#:~:text=URL%3A%20https%3A%2F%2Fwww.gainhealth.org%2Fsites%2Fdefault%2Ffiles%2Fpublications%2Fdocuments%2FMighty>
- GAIN. (2023b). *Regulatory monitoring of national food fortification programs: A policy guidance document*. <https://www.gainhealth.org/sites/default/files/publications/documents/regulatory-monitoring-policy-guidance-doc-2018.pdf>
- GAIN. (2024). *Large-Scale Food Fortification*. Retrieved 5/7/2024 from <https://www.gainhealth.org/impact/programmes/food-fortification/large-scale-food-fortification>
- Garcia-Casal, M. N., Peña-Rosas, J. P., Mclean, M., De-Regil, L. M., Zamora, G., & Groups, C. W. (2016). Fortification of condiments with micronutrients in public health: from proof of concept to scaling up. *Annals of the new York Academy of Sciences*, 1379(1), 38-47.
- Garrett, G., Matthias, D., Keats, E., Mbuya, M., & Wouabe, E. (2019). Doubling down on food fortification to fortify the future. *Seattle, WA: Bill & Melinda Gates Foundation*.
- Gebre, G. G., Chiefebo, D. E., & Kacharo, D. K. (2023). Knowledge, attitude and practice towards malnutrition and micronutrient deficiency among male and female farmers in Ethiopia. *BMC nutrition*, 9(1), 130.
- Geicu-Cristea, M., Popa, E. E., & Tenagashaw, M. W. (2024). Consumers' Perceptions of Fortified Foods. In D. Bogueva (Ed.), *Consumer Perceptions and Food* (pp. 589-604). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-7870-6_28
- Gelman, A. (2008). Scaling regression inputs by dividing by two standard deviations. *Statistics in medicine*, 27(15), 2865-2873.
- Gelman, A., Vehtari, A., Simpson, D., Margossian, C. C., Carpenter, B., Yao, Y., Kennedy, L., Gabry, J., Bürkner, P.-C., & Modrák, M. (2020). Bayesian workflow. *arXiv preprint arXiv:2011.01808*.
- Geny, A., Petitjean, M., Vanwymelbeke-Delannoy, V., & Sulmont-Rossé, C. (2023). IMPACT OF FOOD FORTIFICATION ON NUTRITIONAL OUTCOMES AND ACCEPTABILITY IN OLDER PEOPLE: SYSTEMATIC LITERATURE REVIEW. *Frontiers in nutrition*, 10, 1232502.
- Ghasemi, A., & Zahediasl, S. (2012). Normality tests for statistical analysis: a guide for non-statisticians. *Int J Endocrinol Metab*, 10(2), 486-489. <https://doi.org/10.5812/ijem.3505>

- Gillespie, S., Menon, P., & Kennedy, A. L. (2015). Scaling up impact on nutrition: what will it take? *Adv Nutr*, 6(4), 440-451. <https://doi.org/10.3945/an.115.008276>
- Glanz, K., Rimer, B. K., & Viswanath, K. (2015). *Health behavior: Theory, research, and practice*. John Wiley & Sons.
- Glgorić, K., Chioloro, A., Kıcıman, E., White, R. W., Horvitz, E., & West, R. (2024). Food choice mimicry on a large university campus. *PNAS nexus*, 3(12), pgae517.
- Global Alliance for Improved Nutrition (GAIN), G. H. S., UNICEF. (2015). *National Iodine Survey Report Ghana 2015. 2017. 2017.* <https://www.unicef.org/ghana/media/1296/file/UN735926.pdf>
- GLOPAN. (2016). *Cost of Malnutrition - Global Panel on Agriculture and Food Systems for Nutrition*. Retrieved 13/7/2024 from <https://glopan.org/cost-of-malnutrition>
- Goretzko, D., Siemund, K., & Sterner, P. (2024). Evaluating model fit of measurement models in confirmatory factor analysis. *Educational and Psychological Measurement*, 84(1), 123-144.
- Gosdin, L., Sharma, A. J., Tripp, K., Amoahful, E. F., Mahama, A. B., Selenje, L., Jefferds, M. E., Martorell, R., Ramakrishnan, U., & Addo, O. Y. (2021). A school-based weekly iron and folic acid supplementation program effectively reduces anemia in a prospective cohort of Ghanaian adolescent girls. *The Journal of nutrition*, 151(6), 1646-1655.
- Groskurth, K., Bluemke, M., & Lechner, C. M. (2024). Why we need to abandon fixed cutoffs for goodness-of-fit indices: An extensive simulation and possible solutions. *Behavior research methods*, 56(4), 3891-3914. <https://doi.org/10.3758/s13428-023-02193-3>
- Grün, B., & Hornik, K. (2011). topicmodels: An R Package for Fitting Topic Models. *Journal of statistical software*, 40(13), 1 - 30. <https://doi.org/10.18637/jss.v040.i13>
- Guetterman, T. C., & Fetters, M. D. (2018). Two methodological approaches to the integration of mixed methods and case study designs: A systematic review. *American Behavioral Scientist*, 62(7), 900-918.
- Gupta, P. (2025). A Systematic Review on Women's Participation in Agricultural Work and Nutritional Outcomes. *arXiv preprint arXiv:2504.03202*.
- Hair Jr, J. F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, 109, 101-110.
- Harris-Fry, H., Shrestha, N., Costello, A., & Saville, N. M. (2017). Determinants of intra-household food allocation between adults in South Asia—a systematic review. *International Journal for Equity in Health*, 16, 1-21.
- Hatem, G., Zeidan, J., Goossens, M., & Moreira, C. (2022). Normality testing methods and the importance of skewness and kurtosis in statistical analysis. *BAU Journal-Science and Technology*, 3(2), 7.
- Hawkes, C., Ruel, M. T., Salm, L., Sinclair, B., & Branca, F. (2020). Double-duty actions: seizing programme and policy opportunities to address malnutrition in all its forms. *The lancet*, 395(10218), 142-155.
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science*, 43, 115-135.

- Hernán, M. A., Hernández-Díaz, S., & Robins, J. M. (2004). A structural approach to selection bias. *Epidemiology*, 15(5), 615-625.
- Hess, S. Y., Brown, K. H., Sablah, M., Engle-Stone, R., Aaron, G. J., & Baker, S. K. (2013). Results of Fortification Rapid Assessment Tool (FRAT) surveys in sub-Saharan Africa and suggestions for future modifications of the survey instrument. *Food and nutrition bulletin*, 34(1), 21-38.
- Hickman, L., Thapa, S., Tay, L., Cao, M., & Srinivasan, P. (2022). Text preprocessing for text mining in organizational research: Review and recommendations. *Organizational Research Methods*, 25(1), 114-146.
- Hoddinott, J. F., & Rosegrant, M. W. (2013). Investments to reduce hunger and undernutrition.
- Højsgaard, S., Halekoh, U., & Yan, J. (2006). The R package geepack for generalized estimating equations. *Journal of statistical software*, 15, 1-11.
- Horton, S., & Mannar, M. V. (2018). Economics of food fortification. In *Food Fortification in a Globalized World* (pp. 299-304). Elsevier.
- Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression*. John Wiley & Sons.
- Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288.
- Hubbard, A. E., Ahern, J., Fleischer, N. L., Van der Laan, M., Lippman, S. A., Jewell, N., Bruckner, T., & Satariano, W. A. (2010). To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology*, 21(4), 467-474.
- Huey, S. L., Islam, S., Mehta, N. H., Konieczynski, E. M., Friesen, V. M., Krisher, J. T., Mbuya, M. N., Monterrosa, E. C., Nyangaresi, A. M., & Mehta, S. (2024). Review of the facilitators and barriers to adoption of biofortified foods and food products. *Nutrition Research Reviews*, 1-22.
- Hurrell, R., & Egli, I. (2010). Iron bioavailability and dietary reference values. *The American journal of clinical nutrition*, 91(5), 1461S-1467S.
- Hurrell, R. F. (2021). Iron Fortification Practices and Implications for Iron Addition to Salt. *J Nutr*, 151(Suppl 1), 3s-14s. <https://doi.org/10.1093/jn/nxaa175>
- Hwang, Y., Oh, H.-K., Chung, J. H., Kim, S. W., Kim, J.-H., Kim, J. S., & Shin, M.-H. (2023). Association between urinary iodine concentration and the risk of papillary thyroid cancer by sex and age: a case-control study. *Scientific reports*, 13(1), 2041. <https://doi.org/10.1038/s41598-023-29071-4>
- Jadhav, M. H., Mannar, M. V., & Wesley, A. S. (2019). A case study on the scaling-up of double fortified salt through the public distribution system of a food security program in Uttar Pradesh, India: experiences, challenges, and achievements. *Journal of Global Health Reports*, 3, e2019075.
- Jebb, A. T., Ng, V., & Tay, L. (2021). A review of key Likert scale development advances: 1995–2019. *Frontiers in psychology*, 12, 637547.
- Jing, J. (2024). Confirmatory factor analysis with ordinal variables: A comparison of different estimation methods. In.
- Kaiser, H. F. (1974). An index of factorial simplicity. *psychometrika*, 39(1), 31-36.
- Katenga-Kaunda, L. Z., Iversen, P. O., Kamudoni, P. R., Holmboe-Ottesen, G., & Fjeld, H. E. (2022). Food-based nutrition counselling and education intervention for

- improved diets of pregnant women in rural Malawi: a qualitative study of factors influencing dietary behaviour change. *Public Health Nutrition*, 25(9), 2436-2447.
- Kavle, J. A., & Landry, M. (2018). Addressing barriers to maternal nutrition in low-and middle-income countries: A review of the evidence and programme implications. *Maternal & child nutrition*, 14(1), e12508.
- Keats, E. C., Akseer, N., Thurairajah, P., Cousens, S., & Bhutta, Z. A. (2022). Multiple-micronutrient supplementation in pregnant adolescents in low- and middle-income countries: a systematic review and a meta-analysis of individual participant data. *Nutr Rev*, 80(2), 141-156. <https://doi.org/10.1093/nutrit/nuab004>
- Keats, E. C., Neufeld, L. M., Garrett, G. S., Mbuya, M. N., & Bhutta, Z. A. (2019). Improved micronutrient status and health outcomes in low-and middle-income countries following large-scale fortification: evidence from a systematic review and meta-analysis. *The American journal of clinical nutrition*, 109(6), 1696-1708.
- Klassen-Wigger, P., Geraets, M., Messier, M. C., Detzel, P., Lenoble, H. P., & Barclay, D. V. (2018). Micronutrient fortification of bouillon cubes in Central and West Africa. In *Food fortification in a globalized world* (pp. 363-372). Elsevier.
- Kline, R. B. (2023). *Principles and practice of structural equation modeling*. Guilford publications.
- Kroke, A. M., & Ruthig, J. C. (2024). Conspiracy beliefs predicting health behaviors: an integration of the theory of planned behavior and health belief model. *Current Psychology*, 43(9), 7959-7973. <https://doi.org/10.1007/s12144-023-04953-y>
- Kubuga, C. K., Abizari, A.-R., & Song, W. O. (2019). Iodine status of reproductive age women and their toddlers in northern Ghana improved through household supply of iodized salt and weekly indigenous meal consumption. *PloS one*, 14(5), e0216931.
- Kumordzie, S., Davis, J., Adams, K., Tan, X., Adu-Afarwuah, S., Wessells, K. R., Arnold, C., Becher, E., Haskell, M., & Vosti, S. (2021). Understanding Patterns and Drivers of Bouillon Use in Northern Ghana to Inform Fortification Planning. *Current Developments in Nutrition*, 5, 5140655.
- Kuong, K., Tor, P., Perignon, M., Fiorentino, M., Chamnan, C., Berger, J., Burja, K., Dijkhuizen, M. A., Parker, M., & Roos, N. (2019). Multi-micronutrient fortified rice improved serum zinc and folate concentrations of Cambodian school children. A double-blinded cluster-randomized controlled trial. *Nutrients*, 11(12), 2843.
- Kyei-Arthur, F., Aballo, J., Mahama, A. B., & Adu-Afarwuah, S. (2024). Infant and young child feeding practices among mothers in the pilot Micronutrient Powder Initiative in four geographically and ethnically diverse districts in Ghana. *PloS one*, 19(8), e0307961.
- Kyei-Arthur, F., Situma, R., Aballo, J., Mahama, A. B., Selenje, L., Amoafu, E., & Adu-Afarwuah, S. (2020). Lessons learned from implementing the pilot Micronutrient Powder Initiative in four districts in Ghana. *BMC nutrition*, 6, 1-13.
- Kyriazos, T. A. (2018). Applied psychometrics: sample size and sample power considerations in factor analysis (EFA, CFA) and SEM in general. *Psychology*, 9(08), 2207.
- Lakens, D. (2021). *Sample Size Justification*. <https://doi.org/10.31234/osf.io/9d3yf>

- Lamstein, S., Koniz-Booher, P., Beall, K., Aakesson, A., & Anson, M. (2014). SBCC pathways for improved maternal, infant, and young child nutrition practices. In: SPRING. <https://www.spring-nutrition.org/sites/default/files/publications....>
- Larson, L. M., Cyriac, S., Djimeu, E. W., Mbuya, M. N., & Neufeld, L. M. (2021). Can double fortification of salt with iron and iodine reduce anemia, iron deficiency anemia, iron deficiency, iodine deficiency, and functional outcomes? Evidence of efficacy, effectiveness, and safety. *The Journal of nutrition*, 151, 15S-28S.
- Lee, C.-S., Chen, Y.-C., Tsui, P.-L., & Chiang, M.-C. (2023). Using the Theory of Planned Behavior to Examine the Sustainable Extension of Rural Food Preparation Techniques. *Agriculture*, 13(5), 1012. <https://www.mdpi.com/2077-0472/13/5/1012>
- Lenzner, T. H., Patricia; Neuert, Cornelia E. (2024). Cognitive Pretesting. Mannheim, GESIS – Leibniz Institute for the Social Sciences (GESIS – Survey Guidelines. https://doi.org/DOI: 10.15465/gesis-sg_en_049
- Li, C.-H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. *Behavior research methods*, 48, 936-949.
- Li, C.-H. (2021). Statistical estimation of structural equation models with a mixture of continuous and categorical observed variables. *Behavior research methods*, 53(5), 2191-2213.
- Li, M., & Kong, X. (2023). Comparing Generalized Estimating Equation and Linear Mixed Effects Model for Estimating Marginal Association with Bivariate Continuous Outcomes. *Ophthalmic Epidemiol*, 30(3), 307-316. <https://doi.org/10.1080/09286586.2022.2098984>
- Liang, K.-Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika*, 73(1), 13-22.
- Lin, J. (2021). Introduction to Structural Equation Modeling (SEM) in R with lavaan. *Los Angeles, California*.
- Liu, Q., & Wang, L. (2021). t-Test and ANOVA for data with ceiling and/or floor effects. *Behavior research methods*, 53(1), 264-277.
- Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: guided by information power. *Qualitative health research*, 26(13), 1753-1760.
- Mao, C., Shen, Z., Long, D., Liu, M., Xu, X., Gao, X., Lin, Y., & Wang, X. (2024). Epidemiological study of pediatric nutritional deficiencies: an analysis from the global burden of disease study 2019. *Nutrition Journal*, 23(1), 44.
- Mardia, K. V. (1970). Measures of multivariate skewness and kurtosis with applications. *Biometrika*, 57(3), 519-530.
- Martin, R. D., Guerard, J. B., & Xia, D. Z. (2024). Resurrecting Earnings-to-Price with Robust Control for Outliers. *Journal of Portfolio Management*, 50(9).
- Matthias, D., McDonald, C. M., Archer, N., & Engle-Stone, R. (2022). The role of multiply-fortified table salt and bouillon in food systems transformation. *Nutrients*, 14(5), 989.
- McDermott, M. S., Oliver, M., Simnadis, T., Beck, E. J., Coltman, T., Iverson, D., Caputi, P., & Sharma, R. (2015). The Theory of Planned Behaviour and dietary patterns: A

- systematic review and meta-analysis. *Prev Med*, 81, 150-156.
<https://doi.org/10.1016/j.ypmed.2015.08.020>
- McNeish, D., & Wolf, M. G. (2023). Dynamic fit index cutoffs for confirmatory factor analysis models. *Psychological methods*, 28(1), 61.
- Miassi, Y. E., Dossa, F. K., Zannou, O., Akdemir, Ş., Koca, I., Galanakis, C. M., & Alamri, A. S. (2022). Socio-cultural and economic factors affecting the choice of food diet in West Africa: a two-stage Heckman approach. *Discover Food*, 2(1), 16.
- Mkambula, P., Mbuya, M. N., Rowe, L. A., Sablah, M., Friesen, V. M., Chadha, M., Osei, A. K., Ringholz, C., Vasta, F. C., & Gorstein, J. (2020). The unfinished agenda for food fortification in low-and middle-income countries: quantifying progress, gaps and potential opportunities. *Nutrients*, 12(2), 354.
- Mkandawire, E., Bisai, C., Dyke, E., Dressel, A., Kantayeni, H., Molosoni, B., Kako, P. M., Gondwe, K. W., & Mkandawire-Valhmu, L. (2022). A qualitative assessment of gender roles in child nutrition in Central Malawi. *BMC Public Health*, 22(1), 1392.
- Mohammad, S. M., & Turney, P. D. (2013). Crowdsourcing a word–emotion association lexicon. *Computational intelligence*, 29(3), 436-465.
- Moretti, D., Hurrell, R. F., & Cercamondi, C. I. (2018). Bouillon cubes. In *Food fortification in a globalized world* (pp. 159-165). Elsevier.
- Mw, B. (1993). Alternative ways of assessing model fit. *Testing structural equation models*.
- Naghashpour, M., Shakerinejad, G., Lourizadeh, M. R., Hajinajaf, S., & Jarvandi, F. (2014). Nutrition education based on health belief model improves dietary calcium intake among female students of junior high schools. *J Health Popul Nutr*, 32(3), 420-429.
- Nandwani, P., & Verma, R. (2021). A review on sentiment analysis and emotion detection from text. *Social network analysis and mining*, 11(1), 81.
- Nelson, J. R., Gren, L. H., Dickerson, T. T., Benson, L. S., Manortey, S., Ametepey, R., Avorgbedor, Y. E., & Alder, S. C. (2021). Using the Health Belief Model to explore rural maternal utilisation of skilled health personnel for childbirth delivery: a qualitative study in three districts of the Eastern Region of Ghana.
- Nelson, L. K. (2020). Computational grounded theory: A methodological framework. *Sociological methods & research*, 49(1), 3-42.
- Nemeth, R. (2002). Respondent selection within the household-A modification of the Kish grid. Meeting of young statisticians,
- Norris, K., Jilcott Pitts, S., Reis, H., & Haynes-Maslow, L. (2023). A systematic literature review of nutrition interventions implemented to address food insecurity as a social determinant of health. *Nutrients*, 15(15), 3464.
- Nowakowska, M., Zghebi, S. S., Chen, L. C., Ashcroft, D. M., & Kontopantelis, E. (2023). Examining non-linearity in the association between age and reported opioid use in different socioeconomic strata: cohort study using Health Survey for England waves from 1997 to 2014. *BMJ open*, 13(3), e057428.
<https://doi.org/10.1136/bmjopen-2021-057428>
- Nyumuah, R. O., Hoang, T. C., Amoafu, E. F., Agble, R., Meyer, M., Wirth, J. P., Locatelli-Rossi, L., & Panagides, D. (2012). Implementing large-scale food

- fortification in Ghana: lessons learned. *Food Nutr Bull*, 33(4 Suppl), S293-300. <https://doi.org/10.1177/15648265120334s305>
- Olson, R., Gavin-Smith, B., Ferraboschi, C., & Kraemer, K. (2021). Food Fortification: The Advantages, Disadvantages and Lessons from Sight and Life Programs. *Nutrients*, 13(4). <https://doi.org/10.3390/nu13041118>
- Osendarp, S. J. M., Martinez, H., Garrett, G. S., Neufeld, L. M., De-Regil, L. M., Vossenaar, M., & Darnton-Hill, I. (2018). Large-Scale Food Fortification and Biofortification in Low- and Middle-Income Countries: A Review of Programs, Trends, Challenges, and Evidence Gaps. *Food Nutr Bull*, 39(2), 315-331. <https://doi.org/10.1177/0379572118774229>
- Ozolins, U., Hale, S., Cheng, X., Hyatt, A., & Schofield, P. (2020). Translation and back-translation methodology in health research—a critique. *Expert review of pharmacoeconomics & outcomes research*, 20(1), 69-77.
- Passarelli, S., Free, C. M., Shepon, A., Beal, T., Batis, C., & Golden, C. D. (2024). Global estimation of dietary micronutrient inadequacies: a modelling analysis. *The Lancet Global Health*, 12(10), e1590-e1599. [https://doi.org/10.1016/S2214-109X\(24\)00276-6](https://doi.org/10.1016/S2214-109X(24)00276-6)
- Petry, N., Wirth, J. P., Adu-Afarwuah, S., Wegmuller, R., Woodruff, B. A., Tanumihardjo, S. A., Bentil, H., Donkor, W. E. S., Williams, T. N., Shahab-Ferdows, S., Selenje, L., Mahama, A., Steiner-Asiedu, M., & Rohner, F. (2021). Risk factors for anaemia among Ghanaian women and children vary by population group and climate zone. *Matern Child Nutr*, 17(2), e13076. <https://doi.org/10.1111/mcn.13076>
- Placzek, O. (2021). Socio-economic and demographic aspects of food security and nutrition.
- Plano Clark, V. L. (2017). Mixed methods research. *The Journal of Positive Psychology*, 12(3), 305-306.
- Pourebrahim, F., Omidvar, N., Rezazadeh, A., Eini-Zinab, H., Shirani, P., & Ghodsi, D. (2024). Food security and its association with socioeconomic status and dietary diversity in free living older people in Tehran, Iran. *BMC Geriatrics*, 24(1), 128. <https://doi.org/10.1186/s12877-024-04705-y>
- Prado, E. L., & Dewey, K. G. (2014). Nutrition and brain development in early life. *Nutrition Reviews*, 72(4), 267-284.
- Rai, A., Maharjan, M. R., Harris Fry, H. A., Chhetri, P. K., Wasti, P. C., & Saville, N. M. (2019). Consumption of rice, acceptability and sensory qualities of fortified rice amongst consumers of social safety net rice in Nepal. *PloS one*, 14(10), e0222903.
- Ramírez-Luzuriaga, M. J., Larson, L. M., Mannar, V., & Martorell, R. (2018). Impact of double-fortified salt with iron and iodine on hemoglobin, anemia, and iron deficiency anemia: a systematic review and meta-analysis. *Advances in Nutrition*, 9(3), 207-218.
- Reddy, M. B., Agbemaflé, I., & Armah, S. (2022). Iron Bioavailability: Enhancers and Inhibitors. In C. D. Karakochuk, M. B. Zimmermann, D. Moretti, & K. Kraemer (Eds.), *Nutritional Anemia* (pp. 141-149). Springer International Publishing. https://doi.org/10.1007/978-3-031-14521-6_11
- Roberts, M. E., Stewart, B. M., Tingley, D., Lucas, C., Leder-Luis, J., Gadarian, S. K., Albertson, B., & Rand, D. G. (2014). Structural topic models for open-ended survey responses. *American journal of political science*, 58(4), 1064-1082.

- Rodas-Moya, S., Giudici, F. M., Owolabi, A., Samuel, F., Kodish, S. R., Lachat, C., Abreu, T. C., van het Hof, K. H., Osendarp, S. J., & Brouwer, I. D. (2023). A generic theory of change-based framework with core indicators for monitoring the effectiveness of large-scale food fortification programs in low-and middle-income countries. *Frontiers in nutrition*, 10, 1163273.
- Röder, M., Both, A., & Hinneburg, A. (2015). Exploring the space of topic coherence measures. Proceedings of the eighth ACM international conference on Web search and data mining,
- Rogers, E. (2003). Diffusion of innovations, 5th edn London. UK: Free Press.[Google Scholar].
- Rogers, L. M., Cordero, A. M., Pfeiffer, C. M., Hausman, D. B., Tsang, B. L., De-Regil, L. M., Rosenthal, J., Razzaghi, H., Wong, E. C., Weakland, A. P., & Bailey, L. B. (2018). Global folate status in women of reproductive age: a systematic review with emphasis on methodological issues. *Ann N Y Acad Sci*, 1431(1), 35-57. <https://doi.org/10.1111/nyas.13963>
- Rohner, F., Wirth, J. P., Zeng, W., Petry, N., Donkor, W., Neufeld, L. M., Mkambula, P., Groll, S., Mbuya, M. N., & Friesen, V. M. (2023). Global coverage of mandatory large-scale food fortification programs: a systematic review and meta-analysis. *Advances in Nutrition*.
- Romero, J. D., Feijoo-Garcia, M. A., Nanda, G., Newell, B., & Magana, A. J. (2024). Evaluating the performance of topic modeling techniques with human validation to support qualitative analysis. *Big Data and Cognitive Computing*, 8(10), 132.
- Rönkkö, M., & Cho, E. (2022). An updated guideline for assessing discriminant validity. *Organizational Research Methods*, 25(1), 6-14.
- Rosenstock, I. M. (1974). Historical origins of the health belief model. *Health education monographs*, 2(4), 328-335.
- Rothman, K. J., Greenland, S., & Lash, T. L. (2008). *Modern epidemiology* (Vol. 3). Wolters Kluwer Health/Lippincott Williams & Wilkins Philadelphia.
- Rowe, L. A. (2020). Addressing the Fortification Quality Gap: A Proposed Way Forward. *Nutrients*, 12(12). <https://doi.org/10.3390/nu12123899>
- Ruel, M. T., & Alderman, H. (2013). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *The lancet*, 382(9891), 536-551.
- Saaka, M., Mutaru, S., & Osman, S. M. (2021). Determinants of dietary diversity and its relationship with the nutritional status of pregnant women. *J Nutr Sci*, 10, e14. <https://doi.org/10.1017/jns.2021.6>
- Sajjad, M., Bhatti, A., Hill, B., & Al-Omari, B. (2023). Using the theory of planned behavior to predict factors influencing fast-food consumption among college students. *BMC Public Health*, 23(1), 987. <https://doi.org/10.1186/s12889-023-15923-1>
- Sari, N. P. W. P., Mazenda, A., & Tristiana, R. D. (2024). Health consideration in food consumption: impacts of education level and custom rules adherence.
- Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American journal of Applied Mathematics and statistics*, 9(1), 4-11.
- Silge, J., & Robinson, D. (2016). tidytext: Text mining and analysis using tidy data principles in R. *Journal of Open Source Software*, 1(3), 37.

- Šimkovic, M., & Träuble, B. (2019). Robustness of statistical methods when measure is affected by ceiling and/or floor effect. *PloS one*, 14(8), e0220889.
- Smith, S. C., & Johnston, W. (2021). Challenges in developing validated tools for assessing consumer perceptions of food products in low-resource settings. *Journal of Nutrition Education and Behavior*, 53(2), 123-134.
- Spohrer, R., Knowles, J., Jallier, V., Ndiaye, B., Indorf, C., Guinot, P., & Kupka, R. (2015). Estimation of population iodine intake from iodized salt consumed through bouillon seasoning in Senegal. *Annals of the new York Academy of Sciences*, 1357(1), 43-52.
- Srivastava, S. K., Mishra, A., Singh, S., & Jaiswal, D. (2023). Household food waste and theory of planned behavior: A systematic review and meta-analysis. *Environmental Science and Pollution Research*, 30(43), 97645-97659. <https://doi.org/10.1007/s11356-023-29141-0>
- Stevens, G. A., Beal, T., Mbuya, M. N., Luo, H., Neufeld, L. M., Addo, O. Y., Adu-Afarwuah, S., Alayón, S., Bhutta, Z., & Brown, K. H. (2022). Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys. *The Lancet Global Health*, 10(11), e1590-e1599.
- Stevens, G. A., Paciorek, C. J., Flores-Urrutia, M. C., Borghi, E., Namaste, S., Wirth, J. P., Suchdev, P. S., Ezzati, M., Rohner, F., & Flaxman, S. R. (2022). National, regional, and global estimates of anaemia by severity in women and children for 2000–19: a pooled analysis of population-representative data. *The Lancet Global Health*, 10(5), e627-e639.
- Stevens, J. (2002). *Applied multivariate statistics for the social sciences* (Vol. 4). Lawrence Erlbaum Associates Mahwah, NJ.
- Sujati, H., & Akhyar, M. (2020). Testing the construct validity and reliability of curiosity scale using confirmatory factor analysis. *Journal of Educational and Social Research*, 20(4).
- Tabachnick, B., Fidell, L., & Ullman, J. (2019). Using multivariate statistics (Vol. 6, pp 497–516). In: Boston, MA: Pearson.
- Tabachnick, B. G., & Fidell, L.S. (2019). *Using Multivariate Statistics*, 7th edition. <https://www.pearson.com/en-us/subject-catalog/p/using-multivariate-statistics/P2000000003097?view=educator>
- Tashakkori, A., & Teddlie, C. (2021). *Sage handbook of mixed methods in social & behavioral research*. SAGE publications.
- Tchum, S. K., Arthur, F. K., Adu, B., Sakyi, S. A., Abubakar, L. A., Atibilla, D., Amenga-Etego, S., Oppong, F. B., Dzabeng, F., Amoani, B., Gyan, T., Arhin, E., & Poku-Asante, K. (2021). Impact of iron fortification on anaemia and iron deficiency among pre-school children living in Rural Ghana. *PloS one*, 16(2), e0246362. <https://doi.org/10.1371/journal.pone.0246362>
- Thériault, R., Ben-Shachar, M. S., Patil, I., Lüdecke, D., Wiernik, B. M., & Makowski, D. (2024). Check your outliers! An introduction to identifying statistical outliers in R with easystats. *Behavior research methods*, 56(4), 4162-4172.
- Thompson, L., Becher, E., Adams, K. P., Haile, D., Walker, N., Tong, H., Vosti, S. A., & Engle-Stone, R. (2024). Modeled impacts of bouillon fortification with

- micronutrients on child mortality in Senegal, Burkina Faso, and Nigeria. *Annals of the new York Academy of Sciences*.
- Tsang, S., Royse, C. F., & Terkawi, A. S. (2017). Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine. *Saudi journal of anaesthesia*, 11(Suppl 1), S80-S89.
- Tumilowicz, A., Neufeld, L. M., & Pelto, G. H. (2015). Using ethnography in implementation research to improve nutrition interventions in populations. *Maternal & child nutrition*, 11, 55-72.
- UNICEF. (2017). Ghana micronutrient survey 2017. *UNICEF: Accra, Ghana*.
- UNICEF. (2024). *Large-scale food fortification for the prevention of micronutrient deficiencies in children, women, and communities*. Retrieved 12 August, 2024 from <https://www.unicef.org/sites/default/files/2024-01/UNICEF%20FF%20Guidance-v8.pdf>
- United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. *New York: United Nations, Department of Economic and Social Affairs*, 1, 41.
- University of Ghana, G., of, U., Wisconsin-Madison, KEMRI-Wellcome Trust, & UNICEF. (2017). *Ghana Micronutrient Survey 2017. Accra, Ghana; 2017*. 2017. Retrieved 08/03/2024 from https://groundworkhealth.org/wp-content/uploads/2018/06/UoG-GroundWork_2017-GHANA-MICRONUTRIENT-SURVEY_Final_180607.pdf
- USAID Advancing Nutrition. (2023). *Landscape Analysis of Anemia and Anemia Programming in Northern Ghana*. <https://www.advancingnutrition.org/sites/default/files/2023-11/usaaid-an-landscape-analysis-of-anemia-and-anemia-programing-in-northern-ghana-2023.pdf>
- van de Schoot, R., Depaoli, S., King, R., Kramer, B., Märten, K., Tadesse, M. G., Vannucci, M., Gelman, A., Veen, D., & Willemsen, J. (2021). Bayesian statistics and modelling. *Nature Reviews Methods Primers*, 1(1), 1.
- Vehtari, A., Gelman, A., & Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing*, 27(5), 1413-1432. <https://doi.org/10.1007/s11222-016-9696-4>
- Verbeke, W. (2005). Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants. *Food Quality and Preference*, 16(1), 45-57.
- Vosti, S. A., Kagin, J., Engle-Stone, R., Luo, H., Tarini, A., Clermont, A., Assiene, J. G., Nankap, M., & Brown, K. H. (2020). Strategies to achieve adequate vitamin A intake for young children: options for Cameroon. *Ann N Y Acad Sci*, 1465(1), 161-180. <https://doi.org/10.1111/nyas.14275>
- Waller, A. W., Andrade, J. E., & Mejia, L. A. (2020). Performance factors influencing efficacy and effectiveness of iron fortification programs of condiments for improving anemia prevalence and iron status in populations: a systematic review. *Nutrients*, 12(2), 275.
- Wegmüller, R., Bentil, H., Wirth, J. P., Petry, N., Tanumihardjo, S. A., Allen, L., Williams, T. N., Selenje, L., Mahama, A., Amoahful, E., Steiner-Asiedu, M., Adu-Afarwuah, S., & Rohner, F. (2020). Anemia, micronutrient deficiencies, malaria, hemoglobinopathies and malnutrition in young children and non-pregnant women

- in Ghana: Findings from a national survey. *PloS one*, 15(1), e0228258. <https://doi.org/10.1371/journal.pone.0228258>
- Wells, J. C., Sawaya, A. L., Wibaek, R., Mwangome, M., Poullas, M. S., Yajnik, C. S., & Demaio, A. (2020). The double burden of malnutrition: aetiological pathways and consequences for health. *The lancet*, 395(10217), 75-88.
- Wessells, K. R., Arnold, C. D., Stewart, C. P., Prado, E. L., Abbeddou, S., Adu-Afarwuah, S., Arnold, B. F., Ashorn, P., Ashorn, U., Becquey, E., Brown, K. H., Byrd, K. A., Campbell, R. K., Christian, P., Fernald, L. C. H., Fan, Y. M., Galasso, E., Hess, S. Y., Huybregts, L., . . . Dewey, K. G. (2021). Characteristics that modify the effect of small-quantity lipid-based nutrient supplementation on child anemia and micronutrient status: an individual participant data meta-analysis of randomized controlled trials. *Am J Clin Nutr*, 114(Suppl 1), 68s-94s. <https://doi.org/10.1093/ajcn/nqab276>
- Wessells, K. R., Kumordzie, S. M., Becher, E., Davis, J. N., Nyaaba, K. W., Zyba, S. J., Arnold, C. D., Tan, X., Vosti, S. A., & Adams, K. P. (2023). Acceptability of Multiple Micronutrient-Fortified Bouillon Cubes among Females and Their Households in 2 Districts in The Northern Region of Ghana. *Current Developments in Nutrition*, 102056.
- Wessells, K. R., Kumordzie, S. M., Becher, E., Davis, J. N., Nyaaba, K. W., Zyba, S. J., Arnold, C. D., Tan, X., Vosti, S. A., & Adams, K. P. (2024). Acceptability of multiple micronutrient-fortified bouillon cubes among women and their households in 2 districts in the Northern Region of Ghana. *Current Developments in Nutrition*, 8(1), 102056.
- White, M. (2022). Sample size in quantitative instrument validation studies: A systematic review of articles published in Scopus, 2021. *Heliyon*, 8(12), e12223. <https://doi.org/10.1016/j.heliyon.2022.e12223>
- WHO. (2020). *Micronutrients*. Geneva: World Health Organization. Retrieved 7/04/2024 from https://www.who.int/health-topics/micronutrients#tab=tab_1
- WHO. (2023). *The State of Food Security and Nutrition in the World 2023: Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum* (Vol. 2023). Food & Agriculture Org.
- WHO. (2024a). *Anaemia in women and children: WHO Global Anaemia estimates, 2021 Edition*. https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_children
- WHO. (2024b). *Food Fortification* https://www.who.int/health-topics/food-fortification#tab=tab_1
- WHO. (2024c). *Vitamin A deficiency* <https://www.who.int/data/nutrition/nlis/info/vitamin-a-deficiency>.
- WHO. (2021). *WHO methods and data sources for mean haemoglobin and anaemia estimates in women of reproductive age and pre-school age children 2000-2019*. Retrieved 4/7/2025 from https://cdn.who.int/media/docs/default-source/anaemia-in-women-and-children/hb-methods-for-gather.pdf?sfvrsn=da0fbb5f_11
- Widaman, K. F., & Helm, J. L. (2023). Exploratory factor analysis and confirmatory factor analysis.

- Williams, M. N., Grajales, C. A. G., & Kurkiewicz, D. (2013). Assumptions of multiple regression: Correcting two misconceptions. *Practical assessment, research, and evaluation*, 18(1).
- Wood, S. N. (2017). *Generalized additive models: an introduction with R*. Chapman and Hall/CRC.
- World Bank. (2022). *Nutrition overview*. Retrieved 26/7/2024 from <https://www.worldbank.org/en/topic/nutrition/overview>
- World Food Programme. (2019). *School Feeding in Ghana - Investment Case - Cost Benefit Analysis Report*. Retrieved 28/11/2024 from https://www.wfp.org/publications/school-feeding-ghana-investment-case-cost-benefit-analysis-report?utm_source=chatgpt.com
- Yastica, T. V., Salma, S. A., Caesaron, D., Safrudin, Y. N., & Pramadya, A. R. (2020). Application of theory planned behavior (TPB) and health belief model (HBM) in COVID-19 prevention: a literature review. 2020 6th International Conference on Interactive Digital Media (ICIDM),
- Yiga, P., Mokaya, M., Kiyimba, T., Ogwok, P., Kyallo, F., Koole, J. L., Boedt, T., & Matthys, C. (2024). Measurement of food literacy among the adult population in urban Uganda and Kenya: development and validation of an East African food literacy scale. *Public Health Nutr*, 27(1), e171. <https://doi.org/10.1017/s136898002400168x>
- Zakaria, H., & Laribick, D. B. (2014). Socio-economic determinants of dietary diversity among women of child bearing ages in Northern Ghana.
- Zakariah-Akoto, S., Ankomah, A., Torpey, K., Armar-Klemesu, M., & Aryeetey, R. (2021). Women's participation in the local food system and implications for their dietary quality in rural Northern Ghana: A qualitative study.
- Zimmermann, M. B. (2013). Iodine deficiency and excess in children: worldwide status in 2013. *Endocrine practice*, 19(5), 839-846.
- Zimmermann, M. B., & Andersson, M. (2012). Update on iodine status worldwide. *Current Opinion in Endocrinology, Diabetes and Obesity*, 19(5), 382-387.
- Zimmermann, M. B., & Andersson, M. (2021). GLOBAL ENDOCRINOLOGY: Global perspectives in endocrinology: coverage of iodized salt programs and iodine status in 2020. *Eur J Endocrinol*, 185(1), R13-r21. <https://doi.org/10.1530/eje-21-0171>



APPENDICES

Supplemental material 1: Focus group discussion guide

Qualitative part

FOCUS GROUP DISCUSSION GUIDE

DATE: _____ FGD LOCATION: _____

NUMBER OF FGD PARTICIPANTS: _____ TARGET GROUP: _____

FGD FACILITATOR ID: _____ FGD Note-taker 1 ID: _____ FGD Note-taker 2 ID: _____

FGD START TIME (HH:MM): _____ FGD END TIME (HH:MM): _____

Facilitator's role: Thank you for coming. Today we are going to discuss the bouillon cubes that you received in your households for cooking. I am your facilitator, and my friend will take the notes. I will raise the topics and the issues, and we will discuss them; we would like to know what you think about them. There are no right or wrong answers; would like to hear whatever you have to say. Please do not be afraid or shy to say what you have to say.

To allow the discussion to go smoothly, we let one person speak at a time. Anyone should feel free to disagree or agree with one another. The conversation will be audio-taped (so that we don't miss anything), but we will not record anyone's name. The recording is only for this research; whatever you say will not be linked your name. This session will take about one hour or a bit more. Please, let us all turn off our mobile phones, so we don't get any calls while we are in the meeting. Thank you.

Facilitator/Note Take to note:

- a) Give each participant's unique ID for the purpose of the interview only.
- b) Record the following information from the participants:
 1. Participant's household ID number
 2. Ages of participants
 3. The number of males and females in the group
 4. Participants' level of education
 5. Participants' occupation
 6. participants' positions in the household

draw a map for the study participant in the siting arrangement

Opinions and Attitudes about the CoMIT Bouillon Cubes:

- 1) a) What do you think or observe about the CoMIT bouillon cubes?
 - i. [Probe]: Are there any specific concerns or worries you have regarding the CoMIT bouillon cubes?
 - ii. [Probe]: Have you noticed any differences in the smell or taste of your food when using the CoMIT bouillon cubes?
- c) Have you observed any changes in the health of your family members, particularly women and children, since using the CoMIT bouillon cubes?

2). Benefits of the Study Bouillon Cubes:

What are some of the benefits you believe the study bouillon cubes provide to you and your household members?

- i. [Probe] Which family members do you think would benefit more from continuing to use the cube?

3) Likability of the Bouillon Cubes:

a) What do you like about the household meals prepared with the CoMIT bouillon cubes?

- i. [Probe]: Specifically, regarding the smell of dishes prepared with the cubes, what do you like or dislike?
- ii. [Probe]: In terms of the taste of the food prepared with the cubes, what do you like or dislike?

4) Comparison with Other Bouillon Cubes:

When comparing the CoMIT bouillon cubes your household is receiving with other brands (e.g., Maggi, Onga) you have used before:

a) Do you think the taste of food made with the CoMIT bouillon differs from the taste of food made with other bouillons?

[Probe]: Could you please explain your answer and provide your reasoning?

b) Do you think the smell of food made with the CoMIT bouillon differs from the smell of food made with other bouillons?

[Probe]: Could you please explain your answer and provide your reasoning?

c) Do you find it necessary to use more or less of the CoMIT bouillon to achieve the desired taste or smell compared to other bouillons you have used before?

[Probe]: Could you please explain your answer and provide your reasoning?

5) Changes Observed since Using the Study Bouillon Cubes:

a) Have you noticed any changes in the number of times your household cooks each day since using the CoMIT bouillon cubes?

[Probe]: Please explain how and why you have observed these changes.

b) Have you noticed any changes in the number of cubes your household uses in cooking each day since using the CoMIT bouillon cubes?

[Probe]: Please explain how and why you have observed these changes.

d) Have you noticed any changes in the health of your household members (e.g., energy levels, appetite, frequency of illnesses, children's activity) since using the CoMIT bouillon cubes?

[Probe]: Please explain how and why you have observed these changes.

Acceptance:

1. Are you satisfied or content with your household receiving bouillon cubes from us for cooking?

[Probe]: Could you please explain your answer and provide your reasoning?

2. Are you satisfied or content with the quantity of study bouillon cubes your household is receiving?

[Probe]: Could you please explain your answer and provide your reasoning?

3. When using the CoMIT bouillon cubes to prepare food, what do you like about them? Is it the taste, smell, or color?

[Probe]: Could you please explain your answer and provide your reasoning?

4. When using the CoMIT bouillon cubes to prepare food, is there anything that makes you not enjoy the food?

[Probe]: Could you please explain your answer and provide your reasoning?

5. Would you prefer your household to buy non-study bouillon cubes from the market rather than the study-supplied bouillon cubes?

[Probe]: Could you please explain your answer and provide your reasoning?

a) Would you like your household to continue using the study bouillon cubes in preparing food if they were available on the market?

[Probe]: Could you please explain your answer and provide your reasoning?

b) Would you like to recommend the study bouillon cubes to your neighbor to use?

[Probe]: Could you please explain your answer and provide your reasoning?

6. Which do you prefer: the CoMIT bouillon cubes or the other bouillon your household has used before?

[Probe]: Could you please explain your answer and provide your reasoning?

- a) Would you and your household be willing or happy to use the study bouillon cubes in the future (after the study has ended) if they were available?

[Probe]: Could you please explain your answer and provide your reasoning?

- b) Would you and your household be willing or happy to buy the study bouillon cubes in the future (after the study has ended) if they were available in the market?

[Probe]: Could you please explain your answer and provide your reasoning?

In general, do you have any additional comments or feedback regarding the study bouillon cubes?



Quantitative Questions

Recruitment Phase Questions

Questions: Non-Index Household Member's Background Information

All data from questionnaires (paper and electronic) will be remotely monitored weekly by the UC Davis Statisticians.

Enter the respondent's answer (a number) into the box that has been provided in the RESPONSE column. Questions with answers that are numbers should be written in figures under the RESPONSE column.

Field Worker will say:

I have some questions here for you. I am supposed to ask you each one of them, even if you think I should know the answer, because we want all the answers to come from you. So, please give me your answer to each question as much as you can.

#	QUESTIONS FOR PARTICIPANT	RESPONSE
1	Sex of respondent 1=Male 2=Female <i>You are a male/ You are female, right?</i>	
2	How old are you? (Age in completed years) <i>Enter age in completed years.</i>	
3	Tell me who in your household is/are recruited in the randomised trial 1= WRA only 2= Lactating woman (LW) only 3=Child only 4=WRA and LW 5=WRA and Child 6=LW and Child 7=WRA and LW and Child <i>Enter the number corresponding to the individual(s) enrolled in the RCT.</i>	
4	How are you related to the household head? 1= Self (Household head, HH) 2= Wife of HH 3= Father/Mother of HH 4=Sibling of HH 5=Son/Daughter of HH 6=Other (specify)..... <i>Enter the number corresponding to the participant's relationship to the HH</i>	
5	What is your position in the household when it comes to cooking for the household? 1= Primary cook 2=Secondary cook 3=Occasional cook 4=Rarely or never cook for the household 6=Other (sp).....	

	<i>Enter the number corresponding to the OAA participant's position when it comes to cooking for the household.</i>	
6	What is your highest level of education? 1=Primary 2= JSS 3=SHS 4 = Above SHS <i>Enter the number corresponding to the participant's highest level of education.</i>	
7	Which ethnic group do you belong to? 1= Dagbomba 2= Gonja 3=Mamprusi 66= Other (specify)..... <i>Enter the number corresponding to the participant's ethnic group.</i>	
8	Which religion do you belong to? 1=Islam 2=Christianity 3=Traditional religion 66=other (specify)..... <i>Enter the number corresponding to the participant's religion.</i>	
9	What is your occupation (job or work)? 1= Agriculture/ farming as owner/tenant 2= Homemaker 3= Shop/market/stall/cook 4=Own business 5= Technical/skilled laborer 6 = Government employee 66 = Other, specify _____) <i>NB: Homemaker (a person who manages the household of his or her own family)</i> <i>Enter the number corresponding to the participant's occupation.</i>	

3.2. Perception (Opinions and attitudes) about any bouillon cubes use

For the next set of questions, ask participants about any bouillon cubes used. Start each question with the heading statement, "People who:". Say each question and refer to the level of agreement for the participant to select from. Next, fill in the box with the number that corresponds to the participant's level of agreement. Enter 99 "not applicable" if the participant is not willing to provide an answer. Do not leave any question unanswered.

Field worker will say:

"For the next set of questions, I am going to ask you about any bouillon cubes your household uses during cooking." I would like to know what you think, feel (or believe), and do about any bouillon cube use in household cooking.
I would like you to tell me how you agree with people who think the following about bouillon cubes:

The numbers 1 to 5 represent your level of agreement as follows: *Level of agreement: 1 = **Completely disagree**; 2 = **Disagree**; 3 = **Neither agree nor disagree**; 4 = **Agree**; 5 = **Completely agree**.

People who

#	Question	Level of agreement*					
		1	2	3	4	5	99
1	Think it is ok to use bouillon cubes in cooking food meant for everyone in your household. <i>Enter the number corresponding to the participant's level of agreement.</i>	_	_	_	_	_	_ _
2	Think it is ok to use bouillon cubes to make the food smell nice. <i>Enter the number corresponding to the participant's level of agreement.</i>	_	_	_	_	_	_ _
3	Think it is ok to use bouillon cubes to make the food taste nice. <i>Enter the number corresponding to the participant's level of agreement.</i>	_	_	_	_	_	_ _
4	Think that bouillon cubes can be used in your household every day during the week. <i>Enter the number corresponding to the participant's level of agreement.</i>	_	_	_	_	_	_ _
5	Think that bouillon cubes should be used in your household in some, but not all, of the days of the week. <i>Enter the number corresponding to the participant's level of agreement.</i>	_	_	_	_	_	_ _
6	Think that bouillon cubes can be used in your household any number of times in a day. <i>Enter the number corresponding to the participant's level of agreement.</i>	_	_	_	_	_	_ _
7	Think that bouillon cubes can be used in any food being prepared in your household, if the person preparing the food chooses to do so.	_	_	_	_	_	_ _

	Enter the number corresponding to the participant's level of agreement.						
Read question 8 and enter the number corresponding to the participant's opinion about bouillon cubes: 1 = good; 2 = bad; 3 = neither good nor bad.							
8	Do you think that bouillon cubes are (1) good or (2) bad or (3) neither good nor bad?	_	_	_			
Read questions 9, 10, and 11 in reference to the 5 levels of agreements described above. Enter the number corresponding to the participant's level of agreement.							
#Question		1	2	3	4	5	
9	How do you agree with people who think that bouillon cubes are good.	_	_	_	_	_	_ _
10	How do you agree with people who think that bouillon cubes are bad.	_	_	_	_	_	_ _
11	How do you agree with people who think that bouillon cubes are neither good nor bad?	_	_	_	_	_	_ _
Read question 12 and enter the number (1 or 2) corresponding to the participant's opinion.							
12	Do you think your household members (1) do more cooking when they have bouillon cubes than when they have no bouillon cubes or (2) they don't change their cooking whether they have bouillon cubes or not.	_	_				
Read question 13 and enter the number (1 or 2 or 3) corresponding to the participant's opinion.							
13	Do you (1) like or (2) not like or (3) not really mind the way bouillon is used in your household	_	_	_			
For question 14, please type an participant's response verbatim in the space provided. Do not summarise the response in one word.							
14	If you have anything you would like to say about bouillon cubes in general, we would like to hear it. Probe and enter any comments as text.						

Intervention Phase Questions**3.0. Intervention**

The recruitment period would involve data collection on the background information of the non-index household members and any bouillon cubes used in household cooking. These questions would be administered in two separate timelines: baseline (60 days into the receiving of the study-supply bouillon cubes) and endline (60 days to the exit of the study). The adult household member would be asked the same set of questions at each timeline indicated.

3.1. Questions: Non-index Household Member's Background Information

Enter the respondent's answer (a number) into the box that has been provided in the RESPONSE column. Questions with answers that are numbers should be written in figures under the RESPONSE column.

Field Worker will say:

I have some questions here for you. I am supposed to ask you each one of them, even if you think I should know the answer, because we want all the answers to come from you. So, please give me your answer to each question as much as you can.

#	QUESTIONS FOR PARTICIPANT	RESPONSE
	Date form was completed	/ /
2	Tell me who in your household is/are enrolled in the randomised trial 1= WRA only 2= Lactating woman (LW) only 3=Child only 4=WRA and LW 5=WRA and Child 6=LW and Child 7=WRA and LW and Child <i>Enter the number corresponding to the individual(s) enrolled in the RCT.</i>	
3	Round of quantitative data collection 1=First round 2=Second round 3=Lactating woman <i>Enter the number corresponding to the round of data collection.</i>	
4	During the past 1-2 months, what has been your position in the household when it comes to cooking for the household? 1= Primary cook 2=Secondary cook 3=Occasional cook 4=Rarely a cook 5=Never cook 6=Other (sp)..... <i>Enter the number corresponding to the participant's position when it comes to cooking for the household.</i>	

3.2. Perceptions (Opinions and attitudes) about the study-supplied bouillon cubes

For this section, ask participants about their opinions and attitudes towards the study-supplied bouillon cubes. Say each question and refer to the level of agreement for the participant to select from. Next, fill in the box with the number that corresponds to the participant's level of agreement. Enter 99 “not applicable” if the participant is not willing to provide an answer. Do not leave any question unanswered.

Field worker will say:

I would like to know what you think and feel (or believe) about the CoMIT Project bouillon cubes (i.e. the bouillon your household is receiving from the CoMIT Project). I am going to read some questions or statements to you, and I would like you to tell me how you agree with those questions or statements. Most questions or statements have numbers 1 to 5, with 1 = Completely disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Completely agree.

#	Question	Level of agreement*					
		1	2	3	4	5	99
1	What you used to think, feel, and do about bouillon cube use in household cooking has not changed since your household started receiving bouillon cubes from the study (CoMIT Project). <i>Enter the number corresponding to the participant's level of agreement.</i>						
2	That it is ok to use the study bouillon cubes in cooking food meant for everyone in your household. <i>Enter the number corresponding to the participant's level of agreement.</i>						
3	That the smell from the study bouillon cubes is not different from the other bouillon your household has used before. <i>Enter the number corresponding to the participant's level of agreement.</i>						
4	That the taste of the study bouillon cubes is not different from the other bouillon your household has used before. <i>Enter the number corresponding to the participant's level of agreement.</i>						

5	That the <i>study bouillon cubes</i> can be used in your household every day during the week. <i>Enter the number corresponding to the participant's level of agreement.</i>						
6	That the <i>study bouillon cubes</i> should be used in your household in some, but not all, of the days of the week. <i>Enter the number corresponding to the participant's level of agreement.</i>						
7	That the <i>study bouillon cubes</i> can be used in your household any number of times in a day. <i>Enter the number corresponding to the participant's level of agreement.</i>						
8	That the <i>study bouillon cubes</i> can be used in any food being prepared in your household, if the person preparing the food chooses to do so. <i>Enter the number corresponding to the participant's level of agreement.</i>						
<i>Read question 9 and enter the corresponding number of the participant's response (1 = good, 2 = bad, 3 = neither good nor bad).</i>							
9	Do you think that the <i>study bouillon cubes</i> are (1) good or (2) bad or (3) neither good nor bad or (99) not applicable?						
<i>Say questions 10, 11, and 12 in reference to the 5 levels of agreements described above. Enter the number corresponding to the participant's level of agreement.</i>							
#Question		1	2	3	4	5	
10	How do you agree with those who think that the <i>study bouillon cubes</i> are good?						
11	How do you agree with those who think that the <i>study bouillon cubes</i> are neither good nor bad?						
12	How do you agree with those who think that the <i>study bouillon cubes</i> are bad?						
<i>Read question 13 and enter the number (1 or 2 or 3) corresponding to the participant's opinion.</i>							
13	Do you think your household members (1) do more cooking since you started getting the <i>study bouillon cubes</i> than before, (2) cooking has not changed, or (3) you don't know?						

<i>Read question 14 and stick to the responses provided in the question. Enter the number corresponding to the participant's answer that he or she will select.</i>							
14	Do you think your household uses the study bouillon (1) every time you/they cook, or (2) nearly every time you/they cook, or (3) some of the time you/they cook, (4) once in a while, or (5) you don't know?						
<i>Read question 15 and enter the corresponding number of the participant's response (1 = like, 2 = not like, 3 = don't know).</i>							
15	Do you (1) like or (2) not like the way bouillon is used in your household, or (3) you don't know?						

3.2. Acceptance towards study bouillon cubes

In this section, ask participants about their acceptance of study bouillon cubes. Say each question and refer to the level of agreement for the participant to select from. Next, fill in the box with the number that corresponds to the participant's level of agreement. Enter 99 “not applicable” if the participant is not willing to provide an answer. Do not leave any question unanswered.

Field worker will say:

I would like to know what you say about your household's use of (or willingness to use) the CoMIT Project bouillon cubes (i.e., the bouillon your household is receiving from the CoMIT Project) now and in the future (acceptance). I am going to read you some statements. I would like you to tell me to what extent you agree with these statements. All the statements have numbers 1 to 5 representing your level of agreement, as follows:

***Level of agreement: 1 = Completely disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Completely agree.**

#	Question	Level of agreement*					
		1	2	3	4	5	99
Q16	You like the smell of the study bouillon cubes.						
Q17	You like the taste of the study bouillon cubes.						
Q18	You are okay or happy that your household receives the study bouillon						
Q19	That the quantity of the study bouillon cubes your households receives is just fine.						
Q20	That you and your household members like or enjoy foods prepared using the study bouillon cubes.						

Q21	That you would like your household to also purchase non-study bouillon from the market.	☐	☐	☐	☐	☐	☐
Q22	That in the past month, you think your household should have purchased non-study bouillon from market.	☐	☐	☐	☐	☐	☐
Q23	That you have not observed any problems with using the study bouillon cubes in your household.	☐	☐	☐	☐	☐	☐
Q24	That your household members have not observed any problems with using the study bouillon cubes.	☐	☐	☐	☐	☐	☐
Q25	That you have good things to say about the study bouillon cubes.	☐	☐	☐	☐	☐	☐
Q26	That you do not want your household to continue using the study bouillon.	☐	☐	☐	☐	☐	☐
Q27	That you do not think your neighbours or friends would like the study bouillon.	☐	☐	☐	☐	☐	☐
Q28	That you want your household to use the study bouillon in future if it is available.	☐	☐	☐	☐	☐	☐
Q29	That you would be interested in buying the study bouillon if it is sold in future.	☐	☐	☐	☐	☐	☐

