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Understanding How to Increase Women's Acceptance of and Access to Palm Weevil Larvae in Peri-Urban Communities in the Ashanti Region in Ghana

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Abstract

In low- and middle-income countries like Ghana, women are disproportionately affected by iron-deficiency anemia. Various strategies can effectively reduce iron-deficiency anemia at the population level, including food fortification, supplementation, and dietary improvement. Unfortunately, due to cultural, economic, and resource-related challenges, those have failed to reach Ghanaian women adequately and equitably, resulting in many not meeting their nutritional needs. There is a growing consensus that edible insects could serve as a complementary nutrition-sensitive strategy to alleviate nutritional deficiencies in low-and-middle-income countries. No study has yet examined the factors influencing the feasibility of this strategy for women in Ghana.

The first study was formative research providing a general understanding of Ghanaians' perceptions on the consumption of palm weevil larvae. For the aforementioned strategy to be effective, women need to be willing to consume palm weevil larvae and feed it to their families. Mind mapping and focus group discussions were conducted on 121 Ghanaian women in five peri-urban communities in the Ashanti region and sought insight on the facilitators of palm weevil larvae's consumption, its socio-cultural and economic barriers, as well as women's general knowledge of iron-rich foods and anemia. An inductive thematic analysis of the focus group discussions and mind maps showed that women were generally motivated to consume palm weevil larvae for its nutritional and health benefits. Scarcity, difficult access and disgust, however, were the major barriers to the consumption of palm weevil larvae.

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The second study focused on investigating factors influencing locals' access to palm weevil larvae. Using a mixed-methods approach, the subsequent analysis included: a qualitative assessment of the barriers and facilitators of palm weevil larvae's sale and purchase, and an examination of the relationship between customers' socio-economic and demographic characteristics and their palm weevil larvae purchasing frequency. A total of 97 customers were interviewed at seven markets in the Ashanti region. Findings revealed that storage, distribution, and factors from customers' food environments (including transit time to markets and means of transportation) were the major barriers to palm weevil larvae's access. Over 70% of respondents required at least 15 minutes to reach the closest market with 11% needing over an hour. Further, crosstabulations results showed that men [χ^2 (3, N=97)=15, $p=.05$)] and respondents with high educational attainment [χ^2 (12, N=97)=32, $p=.038$)] were more likely to purchase palm weevil larvae frequently (daily or weekly) than women and respondents with lower educational attainments.

Tomato paste's fortification with palm weevil larvae could help with overcoming access and acceptance barriers. The third study evaluates: 1) consumers' willingness to consume and purchase the fortified product, 2) the sensory attributes responsible for consumers' choices, and 3) whether knowledge about the importance of iron influences consumers' willingness to purchase and consume the fortified tomato paste. A consumer acceptability study was conducted among 88 participants from five communities in Kumasi. Binary logistic regression showed that out of all sensory attributes, color (OR=3.76, 95% CI [1.11, 12.6]) and overall liking (OR=14.6, 95% CI [2.26, 95.1]) are the ones influencing consumers' willingness to pay for the fortified tomato paste and accept it for consumption. Furthermore, over 90% of participants preferred the tomato sauce with the highest concentration of palm weevil larvae (30% w/w), suggesting that a

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higher fortification level should be tested. The addition of palm weevil larvae improved significantly ($p<0.05$) tomato paste's iron and zinc contents (wet basis). Finally, brief nutrition education on palm weevil larvae's benefits was shown to influence consumers' willingness to purchase the fortified tomato paste.

This dissertation offers a nuanced understanding of the factors influencing Ghanaian women's acceptance and access to palm weevil and sheds light on the growing demand for palm weevil larvae and women's desire to be involved in its value chain. With adequate governmental funding to support the domestication of palm weevil larvae and nutrition education interventions, we believe that our findings could promote the feasibility of a community-based food-to-food fortification approach led by women. Women would farm their larvae, add them to their tomato stews for nutritional enhancement and sell them at local markets to generate income, subsequently increasing access and consumption of the insect and improving women's status.

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Résumé

Dans les pays à revenu faible et intermédiaire comme le Ghana, les femmes sont touchées de manière disproportionnée par les carences en micronutriments incluant l'anémie ferriprive. Plusieurs stratégies permettent de réduire efficacement l'anémie ferriprive au niveau populationnel, notamment l'enrichissement des aliments, la supplémentation et l'amélioration du régime alimentaire. Malheureusement, en raison de problèmes culturels, économiques et du manque de ressources, ces stratégies n'ont pas réussi à atteindre les femmes ghanéennes adéquatement et équitablement. Ainsi, un grand nombre d'entre elles ne satisfont toujours pas leurs besoins nutritionnels. On accorde de plus en plus d'importance au potentiel des insectes comestibles à servir de stratégie complémentaire pour atténuer les carences nutritionnelles dans les pays à revenu faible ou intermédiaire. Aucune étude n'a encore examiné la faisabilité de cette stratégie pour les femmes au Ghana.

La première étude était une recherche formative permettant de comprendre les perceptions des Ghanéens sur la consommation de larves de charançon du palmier. Pour que la stratégie susmentionnée soit efficace, les femmes doivent être prêtes à consommer des larves de charançon du palmier et à en nourrir leur famille. Des schémas conceptuels et entretiens de groupe ont été menés auprès de 121 femmes ghanéennes dans cinq communautés périurbaines de la région d'Ashanti, afin d'obtenir des informations sur les facteurs facilitant la consommation de larves de charançon du palmier, les obstacles socioculturels et économiques, ainsi que les connaissances générales des femmes sur les aliments riches en fer et l'anémie. Une analyse thématique inductive des discussions de groupe et des cartes mentales a montré que les femmes étaient généralement motivées à consommer des larves de charançon du palmier pour ses

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bénéfices nutritionnels. Cependant, la rareté, l'accès difficile et le dégoût étaient les principales barrières à la consommation de larves de charançon de palmier.

La deuxième étude s'est concentrée sur les facteurs influençant l'accès des locaux aux larves de charançon du palmier. En utilisant une approche mixte, l'analyse subséquente comprend : une évaluation qualitative des obstacles et des facilitateurs de la vente et de l'achat de larves de charançon de palmier, et un examen de l'association entre les caractéristiques socio-économiques et démographiques des consommateurs et leur fréquence d'achat des larves de charançon de palmier. Au total, 97 clients ont été interrogés dans sept marchés dans la région d'Ashanti. Les résultats ont révélé que le stockage, la distribution et les facteurs liés à l'environnement alimentaire des clients (notamment le temps de transit vers les marchés et les moyens de transport) constituaient les principaux obstacles à l'accès aux larves du charançon du palmier. Plus de 70% des personnes interrogées avaient besoin d'au moins 15 minutes pour atteindre le marché le plus proche, avec 11% ayant besoin de plus d'une heure. De plus, les résultats des tableaux croisés ont montré que les hommes [$\chi 2$ (3, N=97)=15, p=.05)] et les répondants ayant un niveau d'éducation élevé [$\chi 2$ (12, N=97)=32, p=.038)] étaient plus susceptibles d'acheter des larves de charançon du palmier fréquemment (quotidiennement ou hebdomadairement) que les femmes et les participants ayant un niveau d'éducation plus faible.

L'enrichissement du concentré de tomates avec des larves de charançon du palmier pourrait aider à surmonter les obstacles à l'accès et à l'acceptation. La troisième étude évalue ainsi : 1) la volonté des consommateurs de consommer et d'acheter le produit fortifié, 2) les attributs sensoriels responsables de l'acceptation des consommateurs, et 3) si la connaissance de l'importance du fer influence la volonté des consommateurs d'acheter et de consommer le concentré de tomates fortifié. Une étude d'acceptabilité par les consommateurs a été menée

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auprès de 88 participants issus de cinq communautés dans la région d'Ashanti. La régression logistique binaire a montré que, parmi tous les attributs sensoriels, la couleur (OR=3,76, IC 95 % [1,11, 12,6]) et l'appréciation générale (OR=14,6, IC 95 % [2,26, 95,1]) sont ceux ayant influencé les consommateurs à vouloir payer pour le concentré de tomate enrichi et l'accepter pour la consommation. En outre, plus de 90 % des participants ont préféré la sauce tomate contenant la plus forte concentration de larves de charançon du palmier (30 % p/p), ce qui suggère qu'un niveau de fortification plus élevé devrait être testé. L'ajout de larves de charançon du palmier a amélioré de manière significative ($p<0,05$) les teneurs en fer et zinc de la pâte de tomate. Enfin, il a été démontré qu'une brève éducation nutritionnelle sur les avantages des larves de charançon de palmier a influencé la volonté des consommateurs d'acheter le concentré de tomates fortifié.

Cette thèse offre une compréhension nuancée des facteurs influençant l'acceptation et l'accès des femmes ghanéennes aux larves de charançon du palmier et met en lumière la demande croissante des larves et l'intérêt des femmes d'être impliquées dans sa chaîne de valeur. Avec un financement gouvernemental adéquat permettant de soutenir la domestication des larves de charançon du palmier et des interventions d'éducation nutritionnelle, nous pensons que nos résultats pourraient soutenir la domestication communautaire des larves de charançons qui serait menée par les femmes, pour les femmes. Les femmes élèveraient leurs larves, les utiliseraient pour enrichir leurs concentrés de tomates en fer et les vendraient sur les marchés locaux pour générer des revenus, augmentant ainsi l'accès et la consommation de l'insecte et améliorant le statut en fer des femmes.

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Contributions to knowledge

This thesis has contributed to an improved understanding of the factors influencing the access and consumption of palm weevil larvae in a peri-urban context in Ghana. These factors can be extrapolated to similar settings. This dissertation builds the rationale of using edible insects as food-based strategies to alleviate micronutrient deficiencies in low-and-middle-income countries.

Chapter 3

This chapter assessed women's perceptions and beliefs about the consumption of palm weevil larvae in peri-urban communities and identified the facilitators and barriers to its use. Findings revealed that women viewed palm weevil larvae as a nutritious and tasty food source. Women were also in favor of processing strategies aiming at increasing palm weevil larvae's accessibility, should health professionals support them. Women revealed an interest to be involved in palm weevil larvae's value chain to generate an additional income stream. Contrary to the narrative commonly found in the literature, our results highlighted that palm weevil larva's limited consumption and use in Ghana were associated with its scarcity and difficult access, mainly, followed by neophobia. Our findings also showed no significant differences in women's perceptions about palm weevil larvae based on their proximity to palm trees.

Chapter 4

Acknowledging access as the main barrier to the consumption of palm weevil larvae in the Ashanti region in Ghana and seeing sale and marketability as a means to increase accessibility, this chapter assessed the contextual, economic, and socio-demographic factors influencing Ghanaian locals' access to palm weevil larvae. In addition, this chapter identified strategies to

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maximize the sale and, as a result, accessibility of palm weevil larvae for Ghanaian women. Results from the cross-tabulations showed that gender and educational attainment were significantly associated with frequent purchasing of palm weevil larvae. This finding confirmed that palm weevil larvae were still a delicacy for Ghanaians. In addition, our findings revealed that internal and external factors from customers' food environments had the highest influence on their palm weevil larvae purchasing frequency. These factors included customers' trust and familiarity with the larva's origin, customers' food literacy, awareness of palm weevil larvae purchasing locations, available infrastructure to travel to these locations, and palm weevil larvae's taste, quality and price. Results from Chapters 3 and 4 support the need for a community-based domestication of palm weevil larvae.

Chapter 5

Drawing from the previous chapters' findings, this chapter explored the effectiveness of fortifying tomato paste with palm weevil larvae on increasing both women's access and consumption of palm weevil larvae and women's iron intake. Our findings confirmed that fortifying tomato paste with palm weevil larvae would increase women's willingness to consume and purchase the insect and feed it to their households. In addition, we found that the addition of 30% (w/w) palm weevil larvae increased significantly tomato paste's iron and zinc contents. This chapter displayed tomato paste as an adequate fortification vehicle for palm weevil larvae that could be made widely available and accessible in Ghana. Our findings therefore could provide the Ghanaian government a rationale for the fortification of tomato products with palm weevil larvae to offer women a complementary source of iron and preserve palm weevil larvae's endangered local knowledge.

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Contribution of authors

For the first manuscript, the candidate designed the protocol and research instruments, oversaw field data collection in peri-urban communities in Ghana, and cleaned the data. Support and supervision for field data collection were provided by Mrs. Esi Nana Aduku. The candidate analyzed the transcripts and wrote the draft manuscript. The candidate also carried out statistical analyses and wrote the first draft manuscript. Dr Melgar Quinonez and Dr Marquis provided significant help with data presentation and interpretation. The manuscript was reviewed several times and critical input was provided by Dr Melgar Quinonez and Dr Marquis.

For the second manuscript, the candidate designed the protocol and the research instruments, oversaw field data collection remotely with the assistance of Mrs. Esi Nana Aduku. The candidate also carried out statistical analyses and wrote the first draft manuscript. The candidate received critical input from Dr. Melgar-Quinonez on the presentation and interpretation of results and revision of the draft manuscript.

For the third manuscript, the candidate designed the protocol and research instruments, oversaw field data collection remotely with significant help and direction from Dr. Karboune. The candidate carried out the statistical analyses and wrote the first draft of the third manuscript. Dr. Melgar-Quinonez and Dr. Karboune provided significant input with the interpretation of results and revision of the third draft manuscript.

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Dedication

This doctoral thesis is dedicated to my late mother, Guitta Haddad and my father, Jean Chamoun.

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List of abbreviations

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ASF	Animal-source food
CGIAR	Consultative Group for International Agricultural Research
FA	Fatty Acids
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
Hb	Hemoglobin
HFP	Homestead Food Production
GHC	Ghanaian cedis
GHG	Greenhouse gas emissions
GHS	Ghana Health Service
GSA	Ghana Standards Authority
IDA	Iron-deficiency anemia
IFA	Iron and Folic Acid
KNUST	Kwame Nkrumah University of Science and Technology
LMICs	Low- and Middle-Income Countries
MANOVA	Multivariate Analysis of Variance
MoFA	Ministry of Food and Agriculture
NTFP	Non-Timber Forest Products
NPGC	Non-palm-growing communities
NUS	Neglected or Underutilized Species
PGC	Palm-Growing Communities
WHO	World Health Organization
WRA	Women of Reproductive Age
WTP	Willingness to pay

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CHAPTER 1: INTRODUCTION

1.1 Background and rationale

Anemia is a major public health concern that affected over 30% of women of reproductive age (WRA) globally in 2019 (World Health Organization, 2022). According to the World Health Organization (WHO), anemia is a condition in which the number of red blood cells or their oxygen-carrying capacity is insufficient to meet physiologic needs (World Health Organization, 2017). Anemia is characterized as having hemoglobin (Hb) levels below 12.0 and 13.0 g/dL in women and men, respectively (World Health Organization, 2017). There are multiple factors associated with anemia; however, nutritional deficiencies are its most common etiologies, with iron deficiency being responsible for around 50% of all anemia cases globally and resulting in iron-deficiency anemia (IDA) (Stoltzfus, 2003). Iron-deficiency anemia is a consequence of severe iron depletion and generally occurs when iron demands by the body are not met by iron absorption (World Health Organization, 2017). Individuals with IDA usually have inadequate dietary intake of iron (less than 18 milligrams of iron per day) and can suffer impaired thermoregulation, immune dysfunction, gastrointestinal dysfunction, and impaired brain and cognitive development (Rasmussen, 2001; Stoltzfus, 2003; World Health Organization, 2017). Anemia also reduces workers' productivity which is problematic in developing countries where income generation is heavily reliant on physical labor (Kassebaum et al., 2014; Stoltzfus, 2003). In Ghana, anemia is considered a moderate public health problem for children and WRA according to WHO's classification (World Health Organization, 2011). In 2019, IDA affected over 35% of Ghanaian WRA, disproportionately affecting more women in the Northern Belt comprising of the Northern, Upper East, and Upper West regions (Wegmüller et al., 2020).

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Three main strategies exist to specifically address iron-deficiency anemia: iron supplementation, food fortification and dietary diversification, and biofortification (World Health Organization, 2017). In 2010, the government of Ghana developed mandatory food fortification standards for iron in wheat flour as a means to tackle iron-deficiency anemia. A nationally representative survey conducted in 2011 noted, however, that only 13% of wheat flour samples were adequately fortified and that Ghanaians' wheat flour consumption level was below 75 grams per day (WHO's recommended level for choosing a food vehicle) (Allen, De Benoist, Dary, Hurrell, & Organization, 2006; Nyumuah et al., 2012). As a result, the additional amount of iron provided through wheat flour fortification was insufficient to meet Ghanaians' needs (Nyumuah et al., 2012). In addition to the inadequate and inconsistent fortification of wheat flour, the aforementioned strategies' lack of success in Ghana has been attributed to the inequitable and unreliable distribution of supplements to women despite establishing the Girls' Iron-Folate Tablet Supplementation program, and to women's low adherence to supplementation (due to forgetfulness to take the supplements, fear of side effects, and poor knowledge of iron and anemia) (Appiah, Nkuah, & Bonchel, 2020; Gosdin et al., 2021; Nasir, Fentie, & Adisu, 2020; Saskia J. M. Osendarp et al., 2018).

Consequently, an alternative strategy to curtail iron-deficiency anemia in Ghana would be to increase the consumption of animal-source foods (ASF) such as beef and poultry as they are rich sources of heme-iron (iron's highest bioavailable form) (Nyantakyi-Frimpong et al., 2018). Though effective, the required increase in livestock production would have a major detrimental toll on the environment. Livestock (ruminants) production currently accounts for 80% of the greenhouse gas (GHG) emissions caused by the agricultural sector (McMichael, Powles, Butler, & Uauy, 2007). Increasing livestock production would therefore result in higher GHG emissions

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as well as a higher need for land and freshwater (McMichael et al., 2007). In addition, in Ghana, many rural households are unable to afford ASF to increase the nutrition adequacy of their diets (Agbemafle, Francis, Jensen, & Reddy, 2019), hence questioning the adequacy of this strategy.

Neglected or underutilized species (NUS) such as edible insects are non-commodity crops that belong to a group of thousands of domesticated, semi-domesticated or wild species (Padulosi, Thompson, & Rudebjer, 2013). NUS can contribute to improving nutrition, generating income, maintaining ecosystem health, empowering the poor and marginalized, as well as promoting cultural diversity; however, they have been underexploited by researchers and governmental agencies thus limiting their potential impact (Padulosi et al., 2013). In fact, in addition to being nutritious, many of these species do not require high inputs, can be reared on marginal lands or vertically, can enhance climate resilience, improve agricultural sustainability, and save local ecosystems (Padulosi et al., 2013). With their great adaptability to climatic changes and their income generation potential, NUS can therefore help bridge the production and nutritional gaps in our food and agricultural systems, curb food insecurity and fight micronutrient deficiencies (Padulosi et al., 2013).

Palm weevil larvae are Ghanaian NUS which have been commonly consumed by Akan tribes for centuries (Anankware, 2016). Palm weevil larvae provide between 0.53 milligrams and 8.4 milligrams of iron (both heme and non-heme) per 100 grams of edible matter (as is) with an average of 2.58 milligrams (the high variability could be due to palm weevil's feed and regional differences in insect species). In addition, they provide an average of 10 grams of complete protein (though limiting in tryptophan) and 25 grams of fat per 100 grams of edible matter (Payne, Scarborough, Rayner, & Nonaka, 2016). In addition, palm weevil larva's iron and fat content are higher than that of beef (1.95 milligrams of iron and 9.3 grams of fat per 100 grams

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of edible matter) and chicken (0.88 milligrams of iron and 7.2 grams of fat per 100 g of edible matter) reaffirming its potential as an alternative to ASF (Payne et al., 2016).

1.2 Statement of purpose

Owing to the unaffordability of ASFs, the environmental cost of their production, and the barriers of iron supplementation and wheat flour fortification in Ghana, there is a pressing need for other sources of iron that are viable, sustainable, and accepted by Ghanaians. One of the suggested alternatives is to incorporate palm weevil larvae, an underutilized and neglected edible insect, into Ghanaian women's and their children's diets to enhance their iron consumption.

1.3 Research questions and objectives

This research sought to answer to the following research questions:

Chapter 3

a) What are women's perceptions on consuming palm weevil larvae to increase their iron consumption?

Specific objectives:

- To explore the facilitators and barriers to the consumption of palm weevil larvae in selected communities in Ghana;
- To explore women's knowledge on anemia, iron, and iron-rich foods.

Chapter 4

b) What are the factors influencing Ghanaians' access to palm weevil larvae? What are the factors influencing the sale and purchase of palm weevil larvae?

Specific objectives:

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- To explore the factors influencing the sale and purchase of palm weevil larvae at each step of its value chain;
- To examine the factors influencing access to palm weevil larvae in the Ashanti region;
- To explore the socio-economic and demographic factors associated with customers' purchasing frequency of palm weevil larvae.

Chapter 5

c) Would customers be willing to purchase and consume palm weevil larvae-fortified tomato paste to increase their iron consumption? What sensory attributes influence customers' willingness to consume and purchase palm weevil larvae-fortified products?

Specific objectives:

- To examine palm weevil larvae-fortified tomato paste's sensory attributes that influence consumers' acceptance and willingness to pay for the product;
- To examine whether knowledge about the importance of iron is associated with consumers' willingness to purchase and consume palm weevil larvae-fortified product.

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CHAPTER 2: LITERATURE REVIEW

2.1 Iron deficiency anemia: a global call for action

2.1.1 Overview of anemia globally and its causes

Anemia is described by the World Health Organization as a condition in which the blood hemoglobin (Hb) concentration is below the normal values (World Health Organization, 2017). With a lower Hb concentration, oxygen transport to the tissues is compromised resulting in severe fatigue, reduced physical work capacity and productivity, and shortness of breath, among others (World Health Organization, 2017). In 2019, anemia affected around a third of the global population and over 800 million women and children (Safiri et al., 2021; World Health Organization, 2017). Of the multiple causes of anemia, iron deficiency is the most common one, contributing to almost 50% of all cases of anemia among WRA and 42% among children under the age of five (Balarajan, Ramakrishnan, Ozaltin, Shankar, & Subramanian, 2011; Kassebaum et al., 2014; Safiri et al., 2021; World Health Organization, 2017). Iron deficiency compromises the synthesis of Hb and erythrocytes thus resulting in a nutritional anemia, otherwise known as iron-deficiency anemia (IDA) (World Health Organization, 2017).

If left untreated or improperly treated, anemia could be associated with multiple adverse outcomes in women and children, including maternal mortality, low birth weight and delayed child development. Studies have found associations between iron deficiency, IDA and poor cognitive and motor development in children (Jáuregui-Lobera, 2014). In addition, IDA has been reported to result in anxiety, low mood, depression, and poor physical work performance (Balarajan et al., 2011; Benson et al., 2021). Reduced work productivity could have negative

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consequences for low- and middle-income countries (LMICs) where economies rely heavily on physical labor (Balarajan et al., 2011; World Health Organization, 2017).

Multiple socio-economic and demographic determinants of nutritional anemia have been identified in the literature. Women of reproductive age (WRA) aged between 15 and 49 years, pregnant women, adolescents, and children under the age of five are the most vulnerable to iron-deficiency anemia, followed by elders and men. This is due their higher iron requirements compared to the general population, that is needed for growth and development (in the case of children and adolescents) and to account for blood loss that occurs with menstruations and childbirth (Balarajan et al., 2011; Kassebaum et al., 2014; World Health Organization, 2017). Anemia is also associated with household wealth, educational level, occupation, body mass index and/or area of residence (Amegbor, Borges, Pysklywec, & Sabel, 2022; Balarajan et al., 2011; Kassebaum et al., 2014; Tesfaye, Yemane, Adisu, Asres, & Gedefaw, 2015; Yang, Liu, & Zha, 2018). In Central and West and Sub-Saharan Africa, for instance, studies found that educational level was strongly correlated with the prevalence of anemia among adolescent women (Sagalova et al., 2021), so were their dietary diversity score (Ayensu, Annan, Lutterodt, Edusei, & Peng, 2020) and food insecurity levels (Kunamsi, 2021), while in Sub-Saharan Africa, area of residence, access to land for subsistence farming, and household wealth were additional determinants of anemia among African residents (Amegbor et al., 2022). Lack of dietary diversity was shown to be common among women in LMICs like Sub-Saharan African countries (Torheim, Ferguson, Penrose, & Arimond, 2010). According to a review conducted by Torheim and colleagues (Torheim et al., 2010), women were consequently at a higher risk of inadequate iron intake as compared to women from resource-rich settings. This finding emphasized the need for increased attention to the quality and bioavailability of iron in women's diets (Torheim et al.,

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2010). In South and Southeast Asia, educational level, wealth, marital status and access to improved toilet facilities and water sources were the main predictors of anemia among women (Sunuwar et al., 2020).

2.1.2 Anemia in Ghana and its risk factors

In LMICs, including Ghana, anemia has been associated with food insecurity (Kunamsi, 2021), low socio-economic status, age, unsanitary toilet facilities and water sources, lack of formal education, inflammation exposure (such as high exposure to malaria and helminth infections), residence location, and poor dietary habits (Nicolai Petry et al., 2016; Soares Magalhães & Clements, 2011; Teshale, Tesema, Worku, Yeshaw, & Tessema, 2020).

In Ghana, anemia is considered as a moderate health problem for children and WRA based on the World Health Organization's assessment of anemia severity (Group, 1986). According to the 2021 State of Food Security and Nutrition Report, 35.4% Ghanaian WRA were anemic in 2019 (FAO, 2021). Multiple factors contribute to anemia in Ghanaian women and vary regionally. These variations reflect differences in Ghanaians' dietary habits, food environments, and agroecological conditions (Petry et al., 2021). For Ghanaian women, anemia has mainly been associated with iron and vitamin A deficiency, and inflammation (Petry et al., 2021), with over 40% of total anemia linked to iron deficiency (Wegmüller et al., 2020). Dietary diversity has been shown to be a major factor associated with anemia in African countries such as Ethiopia, Senegal, Cameroon, and Ghana (Ayensu et al., 2020; Jugha, Anchang-Kimbi, Anchang, Mbeng, & Kimbi, 2021; Tamiru & Zinab, 2018; Tine & Adama, 2019). A large proportion of Ghanaian women have insufficient dietary intakes of essential nutrients such as iron, zinc, folate and calcium and do not meet their minimum dietary diversity requirement (Ayensu et al., 2020). The Ghanaian diet is in fact dominated by high monotonous intakes of

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grains and starchy staples, such as maize and millet, which are commonly cultivated in Ghana, and is limited in intake of ASFs (such as poultry, meat and fish) which influence positively hemoglobin levels and iron status (Ayamba, 2018; Callister, Gautney, Aguilar, Chan, & Aguilar, 2020). A study conducted by Galbete *et al.* (2017) described the dietary behaviors of Ghanaians living in urban and rural settings. Two dietary patterns were identified: the "rice, pasta and fish" pattern characterized by high intakes of dairy products, red meat, processed meat, eggs, legumes, rice and pasta, fish, meaty mixed dishes, cakes and sweets, and condiments, was particularly popular in urban Ghana and associated with smoking status (current or former smokers), male sex, high education, high physical activity, and younger age (Galbete et al., 2017). The "roots, tubers, and plantain" pattern characterized by high intakes of refined cereals, fruits, nuts and seeds, roots, tubers and plantain, fermented maize products (such as banku and kenkey), legumes and palm oil was popular in rural Ghana and was associated with older age (Galbete et al., 2017). In addition, the results of this study found that a higher adherence to the "roots, tubers, and plantain" diet was associated with lower intakes of calcium, iron, potassium, zinc, sodium, and some vitamins.

Poor dietary habits are usually linked to inadequate nutritional knowledge which is exacerbated in countries with higher individual and household poverty rates such as sub-Saharan African countries (Moschovis et al., 2018; Teshale et al., 2020). A study conducted in Northern Ghana revealed that women had several misconceptions about anemia's causes and treatments (van den Berg-van Antwerpen, Abu, Louw, & Raubenheimer, 2013). Women stated that some of the causes of anemia were God, standing in the sun, stress, pregnancy, dirty environment, hard work, and malaria (van den Berg-van Antwerpen et al., 2013). As for anemia's preventative measures, women mentioned taking iron supplements, deworming, and constantly weighing their

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children as their main approaches (van den Berg-van Antwerpen et al., 2013). Though women had some knowledge on the prevention of IDA, the study highlighted a significant number of myths and half-truths that Ghanaian women believed which can be addressed through nutrition education. A study conducted in the Ashanti region in Ghana revealed similar findings, stating that most of the adolescents interviewed (over 62%) were anemic but had no knowledge about iron deficiency anemia, its causes and consequences, and its prevention strategies (Wiafe, Apprey, & Annan, 2021). In addition, over 95% of the participants did not know about foods rich in iron or foods that increase or reduce iron absorption (Wiafe et al., 2021).

2.2 Strategies to treat and prevent anemia in low- and middle-income countries

Since anemia is a multifactorial condition arising from inadequate nutrition, chronic disease and infections, interventions designed to address it need to tackle its basic, underlying, and immediate causes (Moorthy, Merrill, Namaste, & Iannotti, 2020). There are two major types of interventions that have been defined in the Lancet's Maternal and Child Nutrition Study Group: nutrition-specific interventions directed at the immediate causes of anemia, including diet and infection, and nutrition-sensitive interventions which address the underlying determinants of anemia such as food insecurity and inadequate maternal and childcare (M. T. Ruel & Alderman, 2013).

Some examples of nutrition-specific interventions that have been used to address anemia in LMICs include iron supplementation, dietary diversification, and iron fortification of foods (M. T. Ruel & Alderman, 2013). Some examples of nutrition-sensitive programmes, which can facilitate the delivery of nutrition-specific interventions, include agricultural interventions such as home gardens and irrigation, improved food security, women empowerment, schooling, sanitation, and hygiene (M. T. Ruel & Alderman, 2013).

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2.2.1 Iron supplementation

Iron and Iron and Folic Acid (IFA) supplementation are very commonly used to prevent IDA in settings where anemia is highly prevalent (over 40% prevalent) and where iron is known to be deficient in the diet (World Health Organization, 2017). IFA has been associated with a 31% reduction in anemia among women according to meta-analysis of systematic reviews conducted by Moorthy et al. (2020) (Moorthy et al., 2020).

The appropriate dose and frequency (intermittent vs. daily) of iron supplementation have long been debated because of the evidence of iron supplementation's adverse side effects in malaria-endemic countries. Daily supplementation for three consecutive months in a year and throughout pregnancy is recommended for menstruating adult women and adolescent girls and pregnant women, respectively living in settings where the prevalence of anemia is larger than 40% (World Health Organization, 2017). In malaria-endemic areas, however, IFA should be provided in conjunction with measures to prevent and treat malaria (World Health Organization, 2017). Intermittent IFA supplementation is also recommended by WHO at a frequency of one supplement per week for non-pregnant women as a means to improve hemoglobin concentrations and reduce the risk of anemia (World Health Organization, 2017).

According to a systemic review conducted by Fite et al. (2021) in Sub-Saharan Africa, women's compliance with IFA during pregnancy was less than 40%, mostly due to lack of knowledge about anemia and IFA supplementation (Fite, Roba, Oljira, Tura, & Yadeta, 2021). Poor health education and knowledge about micronutrients and micronutrient deficiencies has been reported as being the main factor for lack of adherence and compliance to interventions against IDA in several countries like Indonesia, Afghanistan, Bangladesh, Ethiopia, Kenya, Senegal and Nigeria (Mora, 2002; Siekmans, Roche, Kung'u, Desrochers, & De-Regil, 2018;

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Triharini et al., 2018). These results were also corroborated with findings related to vitamin A supplementation in Ghana where women's adherence to it was limited by low knowledge of vitamins, false expectations of the supplement, forgetting to take the supplement, losing the supplement, side effects associated with the supplement, concerns about taking the supplement when pregnant, with other medicine or if childless, and concerns about the supplement being used as birth control (Hill et al., 2007). The need for health education about both the importance of vitamins and minerals in women's diets and the benefits and barriers of supplementation is crucial in interventions to increase women's adherence to them. Finally, limited access and availability to low-cost iron tablets was reported as another significant barrier to women's compliance with supplementation (Mora, 2002; Siekmans et al., 2018). One of the reasons for this limitation is that prescription by health professionals is required to access these tablets, meaning women who do not seek health services will not be able to obtain them (Siekmans et al., 2018). These prescriptions have also appeared to be incomplete and insufficient in some cases (Siekmans et al., 2018). In addition, inadequate tablets distribution and storage also limit the availability of iron supplements in LMICs (Mora, 2002).

2.2.2 Dietary diversification and modification

Due to the challenges associated with the implementation of iron supplementation among more vulnerable populations, food-based approaches have been suggested as cost-effective and sustainable alternatives. These approaches include dietary diversification which can be achieved through nutrition-sensitive agriculture interventions in combination with nutrition education.

Dietary diversification and modification

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Dietary diversification consists of increasing the intake of foods that are rich in iron (specifically for IDA), folate and vitamin B12 to help meet nutrient requirements to prevent anemia (World Health Organization, 2017). For iron, dietary diversification strategies need to consider the iron bioavailability of foods, as well as the factors enhancing and inhibiting iron absorption (World Health Organization, 2017). Animal-source foods (ASF) such as meat, fish and poultry are rich sources of bioavailable iron (also known as heme-iron). Some plant sources, on the other hand, are generally rich in non-heme iron which is not well absorbed, unless consumed with iron "enhancers" such as the organic acids citric, malic or ascorbic acid (World Health Organization, 2017). To increase the bioavailability of non-heme iron, the consumption of "inhibitors" such as tannins, polyphenols and phytates found in black and herbal tea, coffee, legumes and cereals should be avoided, and certain food processing techniques such as soaking, germination and fermentation should be favored (World Health Organization, 2017).

The consumption of iron-rich foods consumption could be promoted through nutrition-sensitive agricultural interventions which include homestead ASF production systems and home vegetable gardens (M. T. Ruel & Alderman, 2013; Marie T. Ruel, Quisumbing, & Balagamwala, 2018). A review of interventions based on dietary diversification and modification strategies evaluated the effectiveness of agricultural interventions based on the household production and promotion of ASFs to enhance micronutrient absorption among children and women of reproductive age in LMICs. Dietary diversification and modification strategies can have an impact on behavior change and women's nutritional status if done in conjunction with nutrition education (Gibson & Anderson, 2009). Agricultural interventions based on the production of ASFs at household level have the potential to increase the accessibility and consumption of ASFs by household members, thus increasing the intake of micronutrients such as iron (Gibson &

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Anderson, 2009). In fact, findings from the aforementioned review revealed that two interventions promoting the consumption of ASFs in conjunction with nutrition education in Peru and China decreased significantly the prevalence of anemia among WRA and children, respectively (Gibson & Anderson, 2009).

Homestead food production systems

The evidence on the efficacy of homestead food production (HFP) programs on reducing anemia is inconsistent in the literature. Homestead food production programs are designed to address a particular micronutrient deficiency by providing support for small gardening or ASF production in combination with nutrition education. This approach is considered to be sustainable as it empowers women to take responsibility for their household's diet quality through their own production and nutritional knowledge (Talukder et al., 2014). With iron-deficiency anemia, the aim of HFP programs is to promote year-round production of iron-rich vegetables and ASFs to increase household access to these foods and improve vulnerable populations' iron intake while also improving incomes and livelihoods, and empowering women (Iannotti, Cunningham, & Ruel, 2012). A review presented an impact evaluation of HFP programmes in Bangladesh, Cambodia, Nepal, and the Philippines which integrated a behavioral change component. The evaluated impact indicators included vegetable and animal consumption, anemia in children and women and income earned from HFP (Talukder et al., 2014). Findings from this review showed that HFP programmes improved household garden practices, increased the diversity of the food consumed and produced, and increased consumption of ASFs (Talukder et al., 2014). In addition, the results showed that the food surplus from HFPs was sold to generate income to buy supplementary food items including meat and fish thus increasing the household's dietary diversity (Talukder et al., 2014). In addition, anemia prevalence among non-

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pregnant WRA decreased significantly in communities that implemented HFP programmes Nepal and Bangladesh as compared to control groups where anemia prevalence remained unchanged (Talukder et al., 2014). Similarly, another review which looked at the impact of HFP programmes in Burkina Faso on anemia prevalence found a significant reduction in the latter among children and women (Marie T. Ruel et al., 2018). Finally, in Ghana, a study explored the feasibility of livestock home production to increase household access and consumption of ASFs and reduce anemia among women (Nyantakyi-Frimpong et al., 2018). This study identified the social and economic constraints of livestock production and management which need to be considered when designing interventions to promote ASF consumption and reduce anemia in Ghana (Nyantakyi-Frimpong et al., 2018). Those barriers included limited knowledge about the nutritional values of ASFs, high cost of ASFs, perceived risks of increased exposure to livestock feces which could increase anemia prevalence and intra-household inequalities in ASF consumption. In fact, livestock consumption in Ghana is heavily regulated within families which results in an inequitable allocation among women and children who end up not benefiting from ASF's nutrients (Colecraft et al., 2006; Nyantakyi-Frimpong et al., 2018). Finally, this study showed that producing ASFs for consumption was not the main motivator for raising livestock while income generation is. In fact, ASFs were viewed as a form of savings rather than a source of nutrition (Nyantakyi-Frimpong et al., 2018).

2.2.3 Food fortification

Food fortification refers to the addition of synthetic micronutrients to foods (Allen et al., 2006). Though it has a less immediate impact than iron supplementation, its impact is wider and more sustained and it is usually cost-effective (Allen et al., 2006). For food fortification to be beneficial, the fortified food, also referred to as the "food vehicle", needs to be consumed in

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large amounts by the targeted population, and the fortificant needs to be well absorbed without disrupting the sensory properties of the fortified food (Allen et al., 2006). Food fortification aims to provide 30% to 50% of the daily nutrient requirement for adults at normal consumption levels of the food vehicle (Mannar, 2006). Food fortification was introduced in the early 1920s in Switzerland and the United States of America with iodized salt, before expanding the 1940s with the fortification of cereal products, milk and margarine with vitamins (Allen et al., 2006). Currently, in many developing countries, the fortification of staple foods such as oils and fats, milk, sugar, salt, wheat, rice, or maize flour is a growing trend (Chadare et al., 2019; Mannar, 2006). Fortifying staple foods that are usually less expensive allows reaching more vulnerable populations (Mannar, 2006).

2.2.3.1 Successes of food fortification in LMICs

The success of food fortification interventions has rarely been formally evaluated in fortification programmes making it difficult to assess the actual impact they have had on improving the nutritional status of large populations. An efficacy trial, however, conducted in Vietnam evaluated the efficacy and effectiveness of fortifying fish sauce with iron (in the form of NaFeEDTA) and noted a significant reduction in the prevalence of iron-deficiency anemia within six months going from 69.7% to 20.3% (Chadare et al., 2019).

According to a recent review on the coverage and utilization of food fortification programs in 8 countries (Bangladesh, Cote d'Ivoire, India [Rajasthan], Nigeria, Senegal, South-Africa, Tanzania, and Uganda) the four components of a successful fortification programs are the following: 1) choosing a food vehicle that is fortifiable and widely consumed by the targeted population, 2) programs should be designed based on the extent and distribution of inadequate intake, micronutrient deficiency prevalence, and consumption levels of fortifiable foods, 3)

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effective quality control and monitoring of fortification levels should be performed, and 4) periodic monitoring of nutritional status are required to ensure programs are being impactful (S. J. M. Osendarp et al., 2018).

2.2.3.2 Challenges with food fortification in LMICs

Although the feasibility of food fortification has been demonstrated, a few challenges remain in LMICs. First, food fortification in LMICs lacks effective coverage, otherwise defined as the proportion of the population consuming adequately fortified food (S. J. M. Osendarp et al., 2018). In fact, currently, 46 LMICs had set fortification standards for iron; however, the weighed iron fortification coverage by population size was suboptimal, accounting for only 19% (Tong & Walker, 2021). This variation in coverage was mainly caused by differences in the compliance rate. Low compliance implies that either a small portion of the food vehicle is being fortified, or the fortification is inadequate resulting in a low nutrient intake and subsequently low coverage (Tong & Walker, 2021). Low coverage could also be caused by the choice of inappropriate food vehicles and fortificants, inadequate monitoring of nutritional status, and not reaching populations that are the most in need (S. J. M. Osendarp et al., 2018). Wheat flour is the most commonly fortified food vehicle although it is less consumed than maize corn flour in Africa and rice in Asia, thus contributing to lower coverage rates (Tong & Walker, 2021). Another challenge with large-scale fortification programs is not being able to reach the poorest segments of society who are usually the ones mostly in need, and not considering the inequitable intrahousehold food distribution practices which tend to disadvantage women and young children within households (S. J. M. Osendarp et al., 2018).

2.2.3.3 Iron fortification of foods

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Iron fortification of foods has proven the most difficult as compared to other nutrient-fortification due to the varying absorption of iron compounds as well as the important presence of iron inhibitors in staples foods (which commonly fortified with iron) (Richard F. Hurrell, 2022). As a result, WHO recommends the following iron compounds: ferrous sulfate, ferrous fumarate, encapsulated ferrous sulfate or fumarate, electrolytic iron (at double the iron amount as ferrous sulfate), and ferric pyrophosphate (at double the amount of ferrous sulfate) (Allen et al., 2006). In addition, further steps need to be taken to enhance iron absorption within fortified foods. These include the addition of ascorbic acid, which increases the absorption of iron, and/or processing cereals to reduce their phytic acid levels, thus reducing the inhibition of iron absorption (Richard F. Hurrell, 2022).

2.2.3.4 Wheat flour fortification: mixed-evidence on effectiveness with anemia

Wheat flour has been fortified for several decades with a range of vitamins and minerals. The fortification process involves adding a micronutrient premix into the milled flour. Wheat flour fortification is preferred for iron fortification in populations where there is adequate consumption of industrially milled flour (Richard F Hurrell, 2021). The recommended iron compounds for wheat flour fortification are ferrous sulfate, ferrous fumarate, NaFeEDTA, and electrolytic iron, with NaFeEDTA being preferred for high phytate whole grain wheat flours (Richard F. Hurrell, 2022). The effectiveness of flour fortification on iron status and anemia was first assessed in a systematic review conducted by Pachon et al. (2015) which revealed successful in reducing the prevalence of low ferritin in women of reproductive age, but limited evidence in reducing the prevalence of anemia among them or among children less than 15 years of age (Pachón, Spohrer, Mei, & Serdula, 2015).

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Mandatory legislation for wheat flour fortification has been introduced in 83 countries (Pachón, 2018) consuming more than the 75 grams of flour per capita per day that is needed to adequately fortify cereal flour according to WHO (Allen et al., 2006). However, even with mandatory legislation the impact of wheat flour fortification has been limited in certain countries due to inadequate enforcement of fortification, especially when noncompliance is observed, and poor regulatory monitoring and quality control to ensure the flour produced meets the fortification standards (Luthringer, Rowe, Vossenaar, & Garrett, 2015; Pachón, 2018). These limitations were also experienced in Ghana (Nyumuah et al., 2012).

2.2.3.5 Wheat flour fortification in Ghana

In 2003, the National Food Fortification Alliance designed the Food Fortification project to fortify wheat flour and vegetable oil in Ghana to address anemia and vitamin A deficiency, respectively (Nyumuah et al., 2012). In 2006, Ghana standards were developed to regulate the levels of fortification setting a target of delivering at least 20% of the Recommended Nutrient Intake for iron based on the average consumption of wheat flour (Nyumuah et al., 2012). In 2007, wheat flour fortification officially began in Ghana and became mandatory in 2010 (Dass et al., 2021). A survey conducted in 2011 by the Ghana Food and Drugs Board Authority revealed, however, that only 13% of the wheat flour samples they had tested were adequately fortified (45 parts per million of iron) (Nyumuah et al., 2012). This value kept decreasing over the years with only 5.7% of samples being adequately fortified in 2017 (UNICEF, 2017). Milling companies were having difficulty producing a homogenously fortified product due to feeling reluctant to comply with the national standards stating organoleptic changes and financial losses following fortification (Nyumuah et al., 2012). Due to the highly variable iron concentrations and the low level of wheat consumption in Ghana (60 grams per day as compared to the minimum 75 grams

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per day required by WHO)(Nyumuah et al., 2012), wheat flour fortification did not significantly contribute to increasing iron intake both in urban and rural regions (Dass et al., 2021). More popular food vehicles such as maize which, according to a survey's results, was found to be consumed by 96.8% of the Ghanaian population surveyed should instead be considered for fortification (Dass et al., 2021).

2.2.3.6 Food-to-food fortification

Since conventional food fortification faces economic and processing-related challenges which are exacerbated in LMICs, the development of nutritious and cheap foods from locally available foods becomes an important alternative (Chadare et al., 2019). This approach is named food-to-food fortification and refers to the use of available and accessible local plant or animal underutilized resources to fortify another food (usually a staple food) and fulfill nutritional gaps in a targeted population (Chadare et al., 2019). The effectiveness of food-to-food fortification on increasing the iron content of nutrient-deficient staple foods has been studied using different underutilized nutrient-rich plant species in LMICs. A few examples include the addition of moringa leaf powder to maize flour in Nigeria (Abioye & Aka, 2015), to labneh cheese in Lebanon (Salem, Salama, Hassanein, & El-Ghandour, 2013), and to buttermilk in Pakistan (Nadeem, Javid, Abdullah, Arif, & Mahmood, 2012), or the addition of baobab fruit pulp to Ogi powder in Nigeria (Adejuyitan, Abioye, Otunola, & Oyewole, 2012). Moreover, a study evaluated the addition of cowpea leaves to maize porridges and noted a significant increase in the iron content and bioavailability of the fortified food (Kruger, 2020).

As a result, the use of underutilized species in food-to-food fortification should be further explored as it could have tremendous potential to fight food insecurity, alleviate micronutrient

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deficiencies, generate income, maintain ecosystem health and empower the poor and marginalized (Conti et al., 2019; Padulosi et al., 2013; Teye, Deha, Dadzie, & MacArthur, 2020).

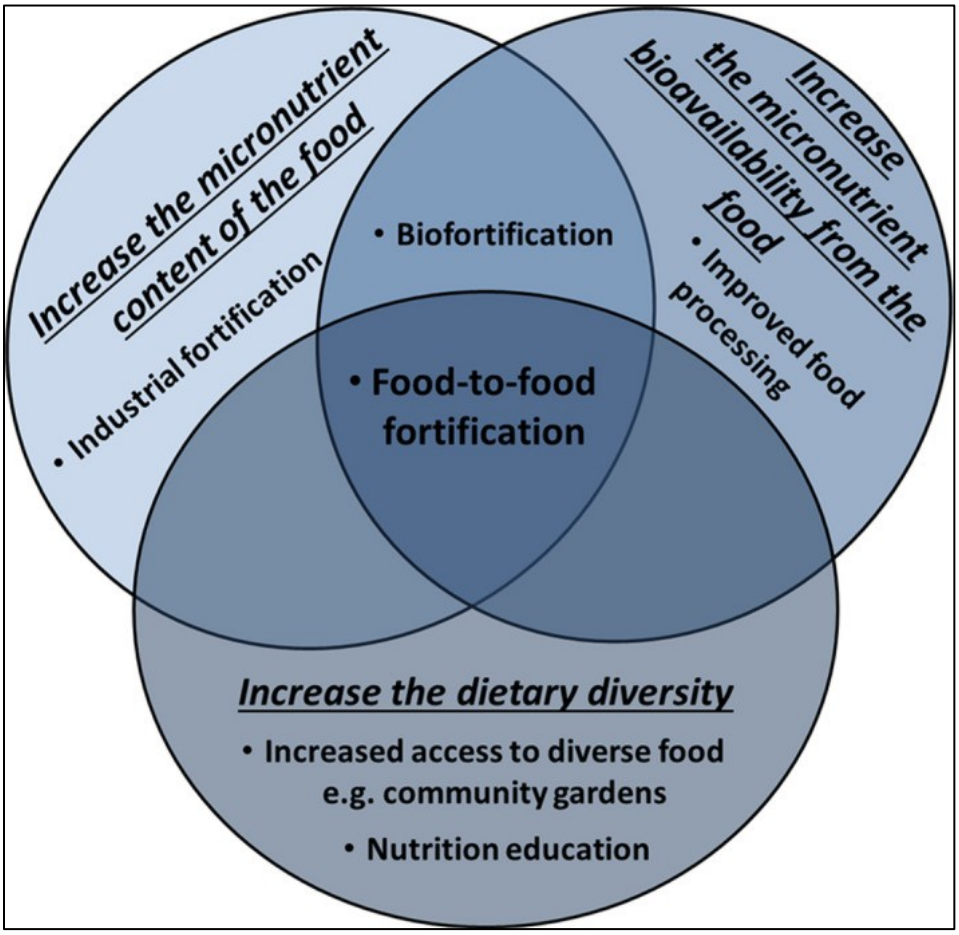

Figure 2.1 Food-based strategies to tackle micronutrient deficiencies caused by inadequate diets. Reprinted from (Kruger, 2020)

2.3 The role of edible insects in alleviating micronutrient deficiencies

2.3.1 Overview of edible insects' consumption globally and in Ghana

Entomophagy, or the practice of consuming edible insects, is popular among multiple cultures. Edible insects are known to be consumed by over two billion people in over 113 countries in Africa, Asia, and Latin America (Raheem et al., 2019; A. Van Huis, Van Itterbeeck, & Klunder, 2014). More than 1900 edible insect species have been reported to be eaten worldwide (Jongema, 2015). The most commonly consumed insects include *Coleoptera* (beetles)

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(31%), *Lepidoptera* (caterpillars) (18%), *Hymenoptera* (ants, bees and wasps) (14%), *Orthoptera* (grasshoppers, locusts and crickets) (13%), *Hemiptera* (cicadas, leafhoppers, planthoppers, scale insects and true bugs) (10%), *Isoptera* (termites) (3%), *Odonata* (dragonflies) (3%) and *Diptera* (flies) (2%) (A. Van Huis et al., 2014). Insects are also consumed at various life-stages (also referred as metamorphic stages) and under different forms: ground, raw, boiled, grilled or fried (Dobermann, Swift, & Field, 2017).

In Africa, edible insects are mostly consumed when staples are scarce and during the rainy season when hunting or fishing can be problematic (A. Van Huis et al., 2014). Edible insects, therefore, have the potential to contribute to food security in Africa; however, this potential is under threat due to a decreased prevalence of traditional practices in several countries where insect consumption used to be common (A. Van Huis et al., 2014). This decrease has mostly been attributed to the increasing spread of Western views of the consumption insects as a source of fear and disgust (Looy, Dunkel, & Wood, 2014). In Asia and particularly in Thailand and Laos, the demand for edible insects has been on the rise due to an increased acceptance for their consumption (Durst & Hanboonsong, 2015). To meet this increasing demand, the procurement of crickets has shifted from being wildly collected to being mass-reared (Hanboonsong, Jamjanya, & Durst, 2013). In Latin America and particularly in Mexico, the gathering and consumption of edible insects has been deeply rooted in the Indigenous people's cultures for centuries and remains a staple in their diets (A. Van Huis et al., 2014).

In Ghana, entomophagy is widely spread. According to a study conducted by Anankware et al. (J. Anankware, E. Osekre, D. Obeng-Ofori, & C. Khamala, 2016) where they surveyed over 2000 Ghanaians, the nine most commonly consumed insects in Ghana are palm weevil larvae, also locally known as *akokono*, followed by termites, ground crickets, grasshoppers,

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locusts, house crickets, shea tree caterpillar, field cricket and finally scarab beetle larva. Palm weevil larvae are consumed by the Akans in the Central, Western, Eastern and the Ashanti Regions, as well as by the Ewes, Gas and Bonos in the Volta, Greater Accra and Brong Ahafo regions, respectively (J. Anankware et al., 2016). *Akokono* are available year round in palm growing communities but are most abundant during the rainy season which spans from May to October. *Akonono* are harvested from trees that have been previously damaged either by human activity in the traditional extraction of sap to make palm wine (Fasoranti & Ajiboye, 1993), or by other insects (Anankware, 2016). Since palm weevil larvae are seasonal and their wild harvesting is dependent on the availability and access to felled palm trees, the process of semi-cultivation has been suggested as an alternative practice than can increase *akokono's* availability and predictability (A. Van Huis et al., 2014). Semi-cultivation is a process whereby an insect's habitat is manipulated to influence its availability or behavior (A. Van Huis et al., 2014). It is a process that requires the use of labor or skill to promote the growth of an organism; however, it does not require the tending of insects (A. Van Huis et al., 2014). Semi-cultivation has the potential to contribute to edible insect habitat conservation, food security, and the preservation of cultural and ecological knowledge (A. Van Huis et al., 2014). The semi-cultivation of palm weevil larvae has gained popularity in Ghana. Palm weevils are first collected from felled trees at either their adult or larval stage. In the latter scenario, they are reared for several weeks in plastic containers and fed a sugarcane diet with fruit waste until they have matured enough to be consumed (A. Van Huis et al., 2014). In the former scenario, they are brought to mate in plastic containers. The produced larvae are then either reared as previously described for consumption purposes, or left to grow into adult weevils to replicate the cycle (A. Van Huis et al., 2014).

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2.3.2 Nutritional and health benefits, and health risks of edible insects

2.3.2.1 Nutritional benefits

The nutritional content of edible insects varies immensely, even within the same species. This variation is attributed to insects' diets and habitats as well as their metamorphic stage (A. Van Huis et al., 2014). Regardless, edible insects provide good amounts of energy, complete protein, monounsaturated and polyunsaturated fatty acids, and are generally rich in micronutrients such as copper, iron, magnesium, phosphorus, manganese, selenium and zinc as well as certain vitamins such as riboflavin, biotin and pantothenic acid (Rumpold & Schlüter, 2013). Protein is a significant component of edible insects, comprising between 30% and 65% of the total dry matter (Dobermann et al., 2017). This is significantly comparable to that of beef (50%), eggs (52%), milk (30%) and soybeans (45%) (Nowakowski, Miller, Miller, Xiao, & Wu, 2022). In addition, edible insects' protein is deemed of good quality as it contains between 46% to 96% of all amino acids but is limited in tryptophan and lysine, and its digestibility is estimated to be between 77% and 98% for most species (Dobermann et al., 2017; Tang et al., 2019). In addition, most edible insects' essential amino acid score varies from 46% to 96%, which is higher than the recommend score of 40% (Nowakowski et al., 2022).

Edible insects tend to be high in unsaturated fats and particularly polyunsaturated fatty acids such as linoleic and linolenic acids which are essential for normal cellular function (Dobermann et al., 2017; Tang et al., 2019). The overall fat content in edible insects varies between 7 to 77 grams per 100 grams of dry weight and larvae are usually better sources of fatty acids than insects at any other stage (Tang et al., 2019). In addition, the most common monounsaturated and saturated fatty acids found in insects are oleic acid and palmitic and stearic acids, respectively (Tang et al., 2019).

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Finally, insects are great sources of vitamins and micronutrients though data on the quantities present are limited for certain species. Insects are, however, undeniably rich sources of iron and good sources of zinc. Iron has been shown to range from 18 milligrams to 1562 milligrams per 100 grams of dry weight across insect species, with the highest levels in crickets (Christensen et al., 2006). The form of iron present in insects has been identified as heme-iron, which is the highly bioavailable form of iron, and its bioavailability has been significantly comparable to that of beef (Latunde-Dada, Yang, & Vera Aviles, 2016). While beef has an average of 12.5 milligrams of zinc per 100 grams of dry weight, palm weevil larvae contain 26.5 milligrams per 100 grams (A. Van Huis et al., 2014). Vitamin A has been found to range from 3 micrograms to 273 micrograms per100 grams of dry weight across insect species, and calcium is present in the range of 33 milligrams to 341 milligrams per 100 grams of dry matter in ants, termites, and crickets (Christensen et al., 2006). A variety of other micronutrients can be found in insects including magnesium, manganese, phosphorus, potassium, selenium, and sodium (Rumpold & Schlüter, 2013). It is important to note that edible insects' macronutrient and micronutrient contents are highly variable and dependent on different species, diets, and life-stages.

2.3.2.2 Health benefits

Several components of edible insects have been shown to benefit humans' health. One of those includes chitin, a type of carbohydrate polymer that constitutes one of the primary components of insects' exoskeleton (Nowakowski et al., 2022). Chitin has been linked to improving human gut microbiota by promoting proliferation of naturally occurring microbiota in the gut, thus helping to prevent incidences of microbial food borne illnesses and food digestion issues (Selenius, Korpela, Salminen, & Gallego, 2018).

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Another component found in is glycosaminoglycan, a polysaccharide with anti-inflammatory properties which was shown to aid in lowering the risk of developing diabetes and chronic inflammatory diseases (Nowakowski et al., 2022). Finally, the medium-chain fatty acid lauric acid, globulin, and albumin proteins which are all commonly found in insects could have antimicrobial effects, increased disease resistance, and increased immune response in animals, respectively (Dobermann et al., 2017). These effects might also translate in humans; however, studies assessing this have not been conducted yet.

2.3.2.3 Health risks

The major health concerns associated with edible insects pertain to their anti-nutrient properties and to possible allergens. Studies on the levels of hydrocyanide, oxalate, phytate, phenol and tannins in edibles insect species found that values fall well below levels of toxicity for human consumption for edible insects; however, chitin, which is present in the exoskeleton of insects, may negatively impact protein digestibility (Dobermann et al., 2017). Data on allergen risk to insects are limited; however, most studies point to the direction that individuals with crustacean allergies will react negatively to insects (Dobermann et al., 2017).

2.3.3 Income generation and food security

The Consultative Group for International Agricultural Research (CGIAR) suggested that one of the solutions to food insecurity in African populations is to encourage the rediscovery and enhancement of local domestic species bearing edible fruit or leaves and edible insects with high nutritional values which are currently neglected and underutilized (Conti et al., 2019). These species are referred to as Neglected and Underutilized (NUS) non-timber forest products (NTFPs) and are defined as “goods derived from forests and other wooded lands that are tangible

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and physical objects of biological origin other than wood" (Muir, Sorrenti, Vantomme, Vidale, & Masiero, 2020). NTFPs, which include foods, medicines, spices, essential oils, plans, wildlife and edible insects, are usually extracted from forests for human use. Edible insects are considered as semi-wild forest products since they have been subjected to human intervention to increase their productivity (Muir et al., 2020). The FAO estimated that NTFPs were used by 80% of the developing world's population to meet some of their financial, health and nutritional needs (Ntiamoa-Baidu, 1997). NTFPs have traditionally provided income and proper nutrition to women in developing countries and have been shown to contribute to improving the livelihoods of forest dependent communities, food and nutrition security, and employment generation (Ahenkan & Boon, 2011; Mulenga, Richardson, Mapemba, & Tembo, 2014).

In Ghana, NTFPs' collection and commercialization have sparked interest in the last decade for their potential to contribute to poverty reduction, food and nutrition security as well as income generation among women (Ahenkan & Boon, 2010; Ahenkan & Boon, 2011). The Center for International Forestry Research (CIFOR) has estimated that over one third of African people rely on NTFPs for income and food security (Temu, 2006). In Ghana, the most popular collected NTFPs are firewood, honey, mushroom, snails, bushmeat, leaves, herbs, cane and pestle (Wongnaa, Ansong, Nkrumah, & Obirikorang, 2018). Furthermore, it has been estimated that over 20% of the economically active Ghanaian population derives income from collecting and selling NTFPs (Ahenkan & Boon, 2010). Recently, the commercial harvesting of palm weevil larvae and other edible insects has gained attention as an income-generating activity. A key step in increasing the income-generating potential of palm weevil larvae is the need to collect sufficient quantities of the raw material for the processing and sale to be profitable. Although palm weevil larvae are available all year long, with a higher abundance near the end of

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the rainy season, (J. P. Anankware, E. A. Osekre, D. Obeng-Ofori, & C. Khamala, 2016; Muafor, Aurele, Le Gall, & Levang, 2015), their harvesting and collection is strenuous, lengthy, and requires some expertise. Collectors can spend days searching, under dire conditions, for the infested trunks of oil palms or raffia stems from which palm weevil larvae are hand-picked (Dounias, 2004; Juanita, Egleé, & Beryl, 2009; Muafor et al., 2015). As a result, due to the limited volume provided through harvesting (Belcher & Schreckenberg, 2007), semi-cultivation and full farming of palm weevil larvae were introduced to enhance the supply of palm weevil larvae and hence its income-generating potential. It has been estimated that the productivity of the semi-farming system is significantly higher than for the traditional gathering method with a single trunk producing 50 ± 10.1 grubs and 35 ± 13.2 grubs, respectively (Muafor et al., 2015). A study conducted in five Ghanaian communities found palm weevil farming as profitable for farmers who were able to generate a net income of over 3000 Ghanaian cedis (local currency) in a year from three production cycles as well as a net profit of around 450 Ghanaian cedis (Commander, Anankware, Royal, & Obeng ofori, 2019). This profitability was also echoed in Namibia where the collection and sale of mopane worms provide valuable income to farmers who sell a 50 kilogram bag sells for over 70 USD on average (Thomas, 2013). Similarly, in Kenya, Mexico and Cambodia, the sale of termites, grasshoppers and crickets, respectively, serve as a livelihood diversification strategy that provides multiple income-generating opportunities for households (A. Van Huis et al., 2014).

2.3.4 Environmental Sustainability

The environmental impact of food production is increasingly being addressed in sustainability debates. There are multiple environmental benefits associated with the rearing of edible insects. Greenhouse gas emissions (GHGs) from the agricultural sector account for 18% to

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22% of total global human-induced emissions measured in CO_2 equivalents, with livestock production contributing to 80% of the sector's emissions (McMichael et al., 2007; A. Van Huis et al., 2014). Methane (CH_4) is produced by enteric fermentation and released from manure while nitric oxide (N_2O) is released mainly from feed crop fertilizer and manure (Huis, 2013). Studies show that the production of 1 kilogram of beef has the highest environmental impact when measured in CO_2 equivalents, followed by pork and chicken (Huis, 2013; Oonincx et al., 2010). Edible insects also produce ammonia and GHGs; however, they emit a hundred times less GHGs and around 35 times less ammonia than livestock (Oonincx et al., 2010). In addition, agriculture consumes 70% of freshwater worldwide. The production of 1 kilogram of beef, pork and chicken requires 22 000 liters, 6000 liters, and 4000 liters of water respectively, while that of crickets and mealworms requires 2500 liters and 4000 liters, respectively (Dobermann et al., 2017). Data on the actual water use of insects are still limited; however, feed conversion efficiency values allow to estimate water requirements needed to produce a given amount of the product. The higher the efficiency, the less feed and water are needed for production (Dobermann et al., 2017). Because insects are cold-blooded and do not require feed to maintain their body temperature, they are more efficient at converting feed to body mass as compared to other livestock, thus requiring far less feed and water than livestock (Huis, 2013; A. Van Huis et al., 2014). In fact, crickets were twice as efficient as chickens, 4 times more efficient than pigs and 12 times more than cattle (Huis, 2013). Finally, Oonincx and de Boer (2010) found that energy usage for the production of 1 kg of mealworm protein was lower than for beef, comparable with pork, and slightly higher than for chicken and milk (Oonincx et al., 2010). In addition, for every 1 hectare of land required to produce mealworm protein, 2.5 times more land would be required for a similar quantity of milk protein, while 3.5 times more land would be

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required to produce a similar quantity of pork or chicken protein, and 10 times more for beef protein (Oonincx et al., 2010). All of the aforementioned factors therefore highlight the environmental benefits of rearing and consuming edible insects as compared to livestock.

2.3.5 Consumer acceptance of edible insects and insect-fortified foods

Though many cultures consume insects as a delicacy or as part of their diets, entomophagy remains unappealing to a lot of people. Aversion for new foods, also referred to as food neophobia, and disgust are the two main barriers to the acceptance of insects as foods, especially in Western cultures (La Barbera, Verneau, Amato, & Grunert, 2018).

A recent review identifying the key factors influencing consumers' acceptance of insect-based foods highlighted that emotional responses, familiarity to taste and textures, social and cultural norms as well as knowledge and education were mostly responsible for increasing consumers' perceptions and acceptance of insects as foods (Wendin & Nyberg, 2021). First, increasing the familiarity to edible insects has been highlighted as crucial in decreasing neophobia among Westerners (Wendin & Nyberg, 2021). In fact, a study conducted on Atlantic Canadians evaluated their perception and acceptability of cricket-based protein powders and found that consumers were more willing to eat insects after having tried them in protein powders (Barton, Richardson, & McSweeney, 2020). These findings highlight the benefit of slowly increasing the exposure to edible insects as a means to increase their acceptability (Barton et al., 2020; Wendin & Nyberg, 2021). One of the strategies directed at encouraging entomophagy through increasing their familiarity is through incorporating processed and concealed edible insects into traditionally consumed food products (de Carvalho, Madureira, & Pintado, 2020; Dobermann et al., 2017; Wendin & Nyberg, 2021). Though this strategy has been effective in some cases, La Barbera et al. (2018) showed that making insects more familiar does not

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automatically make them more acceptable to Westerners as disgust and neophobia are not identical constructs (La Barbera et al., 2018). This suggests that some unfamiliar products do not lead to disgust and unacceptability while some familiar products do lead to disgust and unacceptability. There is, however, a lack of empirical evidence on how neophobia and disgust influence the acceptability of insect-foods and on the effectiveness of increasing insects' familiarity on consumers' willingness to eat insects (La Barbera et al., 2018). Social norms and peer influence also contribute to consumers' acceptability of edible insects. In certain cultures, taboos associated with entomophagy exist and the question of eating animals is connect to ethical issues (Wendin & Nyberg, 2021). Finally, increasing knowledge and awareness of the benefits of entomophagy have had a positive impact on the acceptance of edible insects (Wendin & Nyberg, 2021). As a result, combining information and tasting sessions could potentially increase consumers' exposure to edible insects and reduce the reluctance and disgust they experience (Wendin & Nyberg, 2021).

2.4 Conclusion

Based on the review of the literature, while there is evidence that food-to-food fortification and edible insects could separately reduce micronutrient deficiencies, little is known about the effectiveness of combining both these strategies. In addition, although there is theoretical evidence about factors influencing the acceptance and consumption of edible insects, there is little information about the facilitators and barriers of both insect consumption and access in Ghana. Finally, to date, no socio-economic or demographic factors have been linked to consumers' willingness to eat or purchase palm weevil larvae or palm-weevil larvae products.

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CHAPTER 3: MANUSCRIPT 1

Factors influencing women's acceptance of palm weevil larvae for consumption in peri-urban communities in the Ashanti region, Ghana

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Abstract

For Ghanaian women of reproductive age (WRA), anemia remains a pressing issue. Currently, at the global level, anemia affects 35% of this population according to the most recent "State of Food Security and Nutrition in the World" report. In Ghana, anemia is mostly associated with iron deficiency and, if left untreated, could result in several adverse outcomes including severe fatigue and exhaustion resulting in decreased work productivity, neurocognitive impairment, and complications with chronic kidney disease. Various strategies can effectively reduce iron-deficiency anemia at the population level, including food fortification, supplementation, and dietary improvement. Unfortunately, these have failed to reach Ghanaian women adequately and equitably, resulting in many not meeting their nutritional needs. As an alternative strategy to curtail iron deficiency, edible insects, such as palm weevil larvae, have been suggested for their nutritional benefits, cost-effective rearing, and yearly availability. As such, popularizing their consumption could present an opportunity to improve WRA's iron status in Ghana. To assess the feasibility of this strategy, formative research is needed to examine local attitudes, knowledge, and beliefs associated with the consumption of palm weevil larvae. Formative research was conducted in five peri-urban communities in the Ashanti region of Ghana that were purposefully selected for the study. These communities were separated into two clusters based on their access to palm trees. The analysis was based on 12 focus group discussions conducted with 121 female respondents, at which point data saturation was reached. Thematic analysis was used to examine the facilitators and barriers to palm weevil larvae consumption as well as WRA's general knowledge of nutrition and anemia. Women generally had favorable perceptions of palm weevil larvae as a nutritious food in its raw, frozen, and processed forms, and were eager to be involved in its value chain. The factors positively influencing the acceptance of palm weevil larvae were

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its perceived nutritional and health benefits, and its taste. The main barriers to its consumption in all communities were its scarcity, difficult and inconsistent access, and fear of unauthenticity and unsafety. Finally, despite women's general awareness of the importance of iron, persistent misinformation by health-professionals undermined their perceived seriousness of iron-deficiency anemia. Women's clear interest in palm weevil larvae is encouraging for the community-based domestication of palm weevil larvae. Future studies should examine the feasibility and logistical requirements of such a strategy and its impact on increasing the consumption of palm weevil larvae.

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3.1 Introduction

Micronutrient deficiencies, also called “hidden hunger,” remain a widely prevalent threat to human health. In 2019, 1.7 billion people, including 30% of women of reproductive age (WRA), were estimated to be anemic, with Sub-Saharan Africa holding one of the highest rates for WRA (40%) (FAO, 2021; Gardner & Kassebaum, 2020). In Ghana, despite a slight improvement in the last five years, anemia remains a major public health concern, affecting over 35% of WRA in 2019 (FAO, 2021).

The risk factors associated with anemia vary between countries but generally include iron and vitamin A deficiencies, inflammation, malaria, household sanitation and hygiene, and body mass index (Chaparro & Suchdev, 2019; N. Petry et al., 2016; Wirth et al., 2017). In Ghana, anemia in WRA is mostly associated with iron deficiency (causing iron-deficiency anemia) followed by vitamin A deficiency, and inflammation (Petry et al., 2021).

Various strategies effectively reduce iron-deficiency anemia at the population level, including food fortification, supplementation, and dietary improvement. In Ghana, the implementation of both iron supplementation and iron fortification of wheat flour and vegetable oil did not prove successful in reducing iron-deficiency anemia among WRA. Studies attribute this failure to inadequate and inconsistent fortification across the country, inequitable distribution of supplements, and low adherence to supplementation (due to forgetfulness to take the supplements, fear of side effects, and poor knowledge of iron and anemia) (Appiah et al., 2020; Nasir et al., 2020; Saskia J. M. Osendarp et al., 2018).

Increasing animal source food (ASF) intake, which is an example of dietary improvement, could significantly improve women’s iron status, owing to consumers’ acceptance of ASF, its

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accessibility, and its high content of bioavailable iron (Creed-Kanashiro et al., 2000; Smith, Stull, Patz, & Myers, 2021). While this strategy would benefit the nutritional adequacy of WRA, it would be detrimental to the global environment as it would require scaling up approaches to producing ASF, which currently account for 15% of all greenhouse gas emissions and are expected to double by 2050 (IPCC, 2019; Smith et al., 2021).

The environmental cost of increasing ASF production would be large, which necessitates alternative dietary sources of heme-iron. The United Nations' Food and Agriculture Organization suggested the use of edible insects as an alternative sustainable strategy to curtail iron-deficiency anemia, owing to their rich nutritional composition, low environmental footprint and simple rearing techniques, as highlighted in Figure 3.1 (Arnold van Huis, 2021).

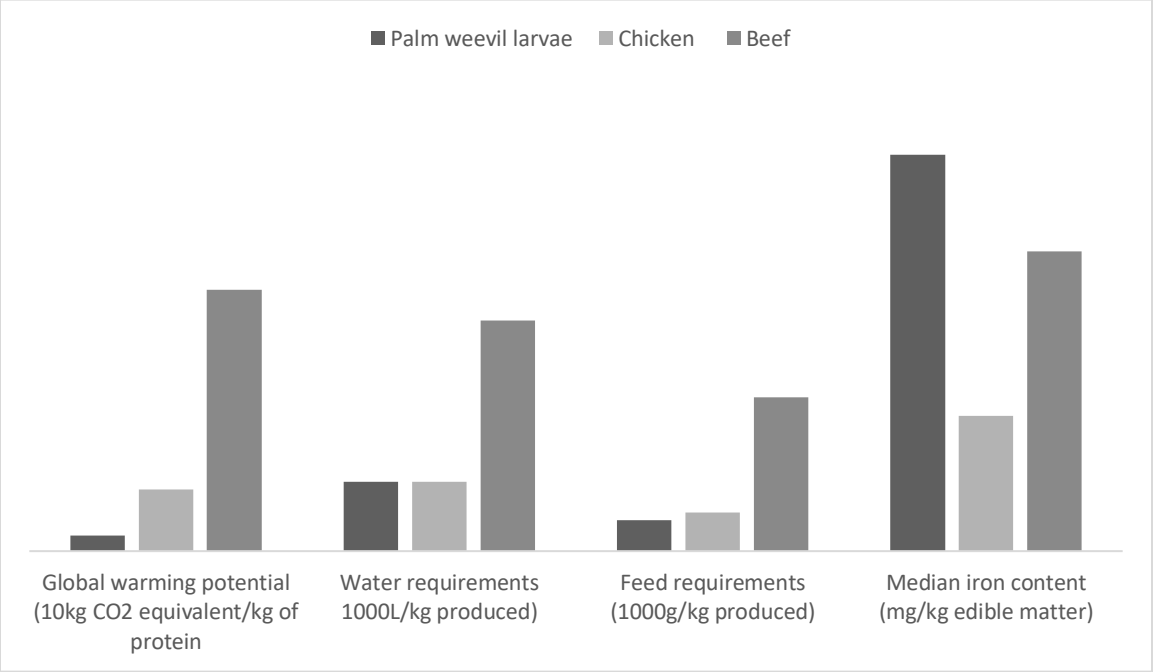

Figure 3.1 Comparison of global warming potential, water and feed requirements, and iron content between palm weevil, chicken, beef. Adapted from Smith et al., 2021 and Oonincx et al., 2010.

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Edible insects have contributed to diets and livelihoods in many cultures, including Thailand, Ghana, Cameroon, Mexico, and Guatemala (Arnold van Huis, 2021). In Ghana, palm weevil larvae, traditionally called *akokono*, are among the most commonly consumed insects and the only ones being semi-cultivated (J. Anankware et al., 2016). Semi-cultivation enables the manipulation of the palm weevil's habitat such that its larva is available throughout the year in larger quantities (Arnold van Huis, 2021) . Since *akokono* is a good source of iron (Mwangi et al., 2018; Parker et al., 2017), popularizing its consumption could present an opportunity to improve WRA's iron status in Ghana. To assess the feasibility of this strategy, formative research is needed to examine local attitudes, knowledge and beliefs associated with the consumption of *akokono,* which has yet to be evaluated in the Ashanti region in Ghana.

The objective of this study was to gain insight into Ghanaian women's acceptance of *akokono* for consumption within their communities, as well as identify the facilitators and barriers to its use.

3.2 Methodology

3.2.1 Study design

A descriptive study design was used to examine the acceptability of palm weevil larvae consumption by women across peri-urban communities in Ghana's Ashanti region to determine the feasibility of palm weevil larvae as a source of iron for women of reproductive age. Qualitative data were obtained through focus group discussions (FGD). As a qualitative approach to gain an in-depth understanding of social issues, focus group discussions are

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described as interactions between pre-selected participants which focus on specific issues (Hennink, 2014).

The objectives of this study were to explore the following: women's attitudes regarding *akokono*, the factors influencing women's propensity to consume it, and women's general knowledge of iron and iron-deficiency anemia. Prior to data collection, institutional review board approval was received from McGill University's Research Ethics Board and Kwame Nkrumah University of Science and Technology's Committee on Human Research, Publication and Ethics.

3.2.2 Study site and participants

The study was conducted between December 2020 and January 2021 in peri-urban communities located in the Ashanti Region of Ghana. A list of identified peri-urban communities surrounding the Kumasi district was compiled using a map designed by Afrane et al. (Afrane & Amoako, 2011), Figure 3.2.

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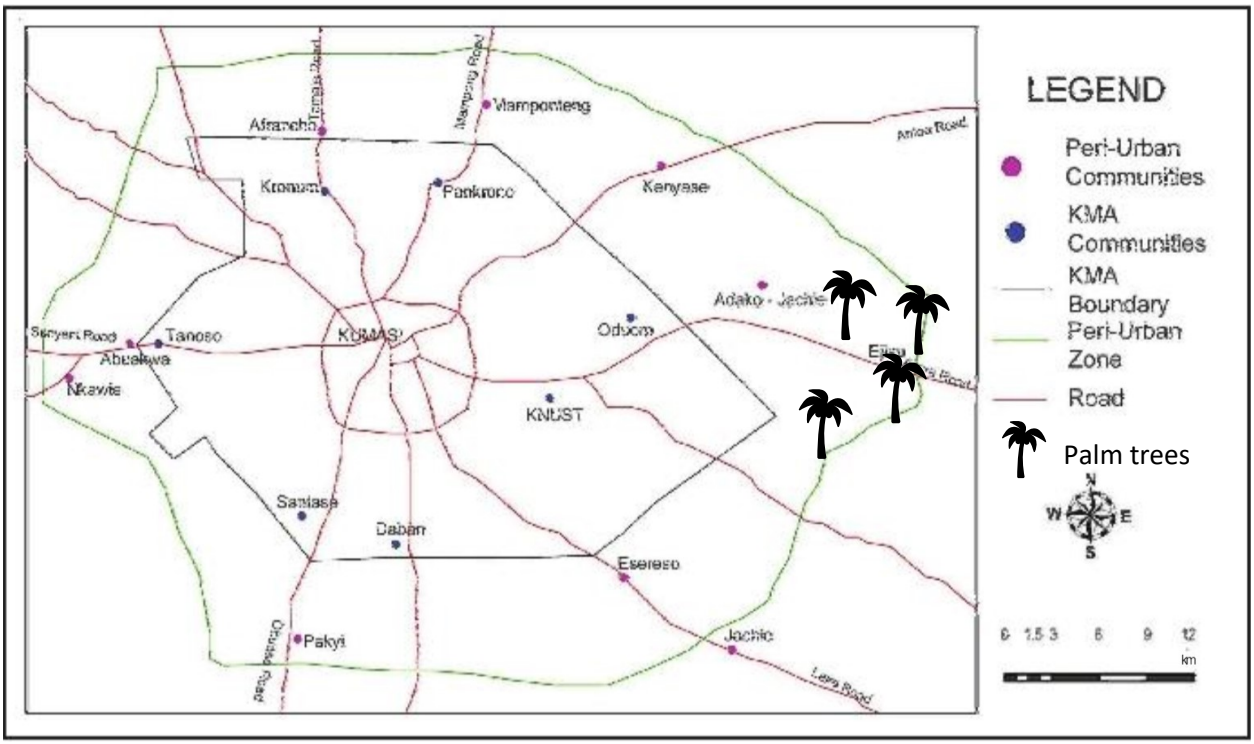

Figure 3.2 Map of peri-urban communities in Ghana with palm tree-rich regions, adapted from Afrane et al. 2011.

Since entomophagy is influenced by various factors that can be location-specific, we found it informative to compare communities based on their access to palm trees. We purposively selected a total of five communities that were separated into two community groups: a) two palm-growing communities (PGC), located in proximity with palm trees, and b) three non-palm-growing communities (NPGC). To protect their anonymity, communities were assigned letters as identifiers.

Key contact people (assembly men and women, and town chiefs) used verbal announcements to inform their communities about the project and recruited participants a few weeks before the start of the data collection. Two FGD with 8 to 13 participants (women >18 years of age) were planned for each of the six communities, for a total of 12 FGD. Those were

held in open areas within the communities. To describe the study and recruit participants, a public announcement was made the day of the data collection in each community.

A total of twelve FGD were completed with 121 women participants, allowing to reach data saturation: four FGD in Community B (n=18); one FGD in Community C (n=12); two FGD in Community D (n=23); three FGD in Community E (n=30); two FGD in Community F (n=22). Written informed consent was obtained from those who agreed to participate.

3.2.3 Data collection

The guide used for the FGD was pre-tested and modified as needed by Ghanaian researchers and research assistants with field experience. Each focus group facilitation team included a moderator as well as a person responsible for taking notes and setting up the video-recorder. Both research assistants were trained to moderate the discussions, engage participants, and build a judgement-free space for participants to fully express themselves. Focus group discussions were conducted in the local language, Twi, and lasted approximately an hour and a half. All participants were told that the FGD was voluntary and that they could decline to answer any questions or complete the focus group even after giving initial consent. Participants' names were kept anonymous. As a token of appreciation, participants received a bar of soap to thank them for their participation.

3.2.4 Data analysis

Each focus group discussion was audio recorded and transcribed verbatim. The transcripts were translated from Twi into English by Ghanaian undergraduate students and typed into an

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electronic copy. Qualitative data were analyzed by the student researcher using the six-stage thematic analysis process recommended by Braun and Clarke (Braun & Clarke, 2006) and guided by the focus group questions. First, the transcripts were read repeatedly for familiarization with the data collected. Transcripts were then imported into the MAXQDA Software version 24, where they were coded. Generated codes were collated into emerging themes and sub-themes, which were subsequently reviewed before being defined and refined. The final step involved writing the analysis.

3.3 Results and Discussion

Focus group discussions allowed to gain an understanding of women's thoughts about *akokono,* their involvement in food preparation, as well as their knowledge of iron-deficiency anemia. An inductive analysis of the transcripts generated a total of four categories, including two nutrition-related, which will be discussed in the sections below.

Previous studies have documented the consumption of *akokono* (J. Anankware et al., 2016) as well as caregivers' perspectives regarding the acceptability of *akokono* as food for infants and young children in the Brong Ahafo region in Ghana (Laar et al., 2017). To our knowledge, this is the first study to explore the factors influencing Ghanaian women's propensity to consume *akokono,* and their general understanding of nutrition, iron and anemia in the Ashanti region.

3.3.1. Perceived facilitators of *akokono* consumption

Participants were generally interested in the consumption of *akokono* for its nutritional and health benefits. Respondents from all communities described *akokono* as being a good

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source of adequate protein and fat to be added to soups and stews. Some participants admitted being inclined to consume *akokono* only because of its health and nutritional benefits. These findings are congruent with studies conducted in other parts of Ghana, Zimbabwe, Uganda, Burundi, India and Brazil (M. Ayieko & V. Oriaro, 2008; Chakravorty, Ghosh, & Meyer-Rochow, 2011; Laar et al., 2017; Lucchese-Cheung, Aguiar, Da Silva, & Pereira, 2020; Manditsera, Lakemond, Fogliano, Zvidzai, & Luning, 2018). Researchers found that taste, nutritional value, medicinal properties, and availability were the main motives for insect consumption in rural and urban areas in the aforementioned countries.

Participants indicated an interest to consume *akokono* both in its frozen and processed forms as a means to increase its preservation and availability all year long, facilitate its cooking, and overcome its scarcity. Participants acknowledged no difference between the processing of *akokono* and that of other meats such as fish and chicken: *"Just like me buying frozen fish and chicken in cold stores, I think I would do same if akokono is frozen." (Community C).* Moreover, participants admitted that adding *akokono* to staple foods would facilitate its consumption, especially among children. Some women mentioned having tried bread and cookies enriched with *akokono* and expressed their willingness to buy such products, should those be available for purchase: *"I have had the opportunity to eat bread made from akokono; therefore, I will buy a product containing akokono." (Community B)*.

3.3.2 Perceived barriers of *akokono* consumption

Respondents clearly articulated their barriers to consuming *akokono* regularly. The main challenges that came up were disgust, scarcity and challenging access, insalubrity, doubt about *akokono's* authenticity, and medical discouragements.

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The most obvious barrier identified by a few participants in both PGC and NPGC groups was their general disgust for insects. For some participants, this barrier completely dissuaded them from potentially trying *akokono: "I don't eat akokono. I can't even stand the sight of them. Their movements make them look disgusting" (Community B).* Disgust is a reaction that has typically been associated with entomophagy in the Westernized world (Arnold van Huis, 2021) and can usually be overridden by incorporating insects in popularly consumed food products and masking their taste and appearance with processing steps and the addition of spices.

Scarcity was perceived as a major barrier for respondents from NPGC and a moderate barrier for respondents from PGC. NPGC participants stated that the irregular availability of *akokono* could make them lose interest in consuming *akokono*. Multiple respondents from PGC highlighted an increase in *akokono*'s scarcity over time which they associated with the erosion and decrease of palm trees caused by the use of chemicals and pesticides. They also mentioned that living close to palm trees did not ensure access to *akokono* as its harvesting is strenuous, unpredictable, and not fruitful. Scarcity due to seasonality, ease of access, and difficulties in collection were also described as main challenges in the utilization of insects in Uganda, Burundi, Nigeria and Cote d'Ivoire (M. Ayieko & V. Oriaro, 2008; CI Ebenebe, Amobi, Udegbala, Ufele, & Nweze, 2017; Niaba et al., 2012). The increasing scarcity of edible insect species has been assessed by researchers and in Zambia, the local extinction of mopani worms has been linked to droughts and the overexploitation of forests making their harvesting non-viable (Ghaly, 2009). Similar results were found in Cameroon where the harvesting of palm weevil larvae, either from naturally infested raffia stems or by cutting and preparing healthy raffia stems for larvae production, has been proven unsustainable and damaging to the forests (Muafor et al., 2015).

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Akokono access can be limited by forest ownership and management in Ghana. Although over 95% of forests are publicly owned in Ghana, they are either jointly managed by local communities and the government, or for most cases, are under the management of "unknown" holders (Food and Agriculture Organization, 2020; Romano & Reeb, 2008). The latter could be explained by forests where ownership is disputed or in transition (Romano & Reeb, 2008). A study looking at oil palm production in Ghana also identified land access as being a critical barrier in shaping farmers' ability to benefit from the cultivation of oil palm (Khatun, Maguire-Rajpaul, Asante, & McDermott, 2020), thus supporting the ambiguity of land and forest management in Ghana.

Although participants expressed a willingness to process *akokono* into food products to make it more available, accessible, and attractive to children, they had concerns regarding the authenticity of *akokono*, its sourcing (naturally harvested versus farmed), the hygienic conditions in which it would be processed, and the possible detrimental changes that the processing could cause to its nutritional and organoleptic properties. Several respondents revealed their willingness to consume *akokono* only if it was harvested from the palm tree, as they felt more reluctant to do so if *akokono* was being manipulated and farmed under controlled conditions in a facility. Our findings about participants' fear of food insalubrity and unsafety concur with a study conducted in Ghana that highlighted consumers' increased concerns about the safety of processed foods due to distrusting public institutions' competence in ensuring food safety (R. Omari, Arthur, & Frempong, 2018).

In addition, participants expressed poor knowledge about where to access *akokono* and how to cook and store it. These comments arose mostly from PGC residents which was surprising considering they lived in close proximity with palm trees and would expectedly be

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more familiar with *akokono.* With the complex forest tenure system in Ghana, however, we understand that physical closeness to palm trees does not ensure access nor utilization of these trees.

With less exposure to *akokono* comes the loss of conversation and knowledge transfer highlighting the importance of educating Ghanaians about the traditional and nutritional values of *akokono.* Another way to raise awareness and contribute to knowledge preservation about *akokono* is by implementing cooking demonstrations within communities. The interest in *akokono*-based food products and nutrition education on *akokono* resurged in a study conducted in other parts of Ghana, namely in the Upper Manya Krobo district, Kumasi Metropolitan, La-Nkwantanang-Madina and Ho municipality (Agbemafle, Francis, Jensen, & Reddy, 2020) pointing to the importance of educating residents on the benefits of *akokono* and *akokono*-based products. This is especially important among children as they greatly influence women with certain household food-related decisions as seen below.

3.3.3 Household decision-making around food and nutrition

While most women reported deciding what to cook based on what their children want to eat, some attributed their decisions to the amount of money and resources available to them. Nutrition did not seem to guide respondents' decisions except for one who mentioned: *"I decide what to cook on a particular day based on what I ate the previous day because I like to keep my meals balanced" (Community B).*

In most cases (n=113), participants who either share the responsibility of purchasing food for the household with their husband or leave it to their husbands, the breadwinners), women acknowledged being in charge of purchasing the food for the household. Our data showed that in

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addition to financial limitations, women's food purchases and preparations were influenced by their children's food choices. This finding is supported by a study conducted in Accra which highlighted family members' (such as mothers, wives, siblings and children) influence on household members' food choices (Boatemaa, Badasu, & de-Graft Aikins, 2018). As women and children play a fundamental role in household food-related decisions, it is crucial to design interventions centered on them.

3.3.4 Knowledge of iron-deficiency anemia

While a few respondents (n=8) had no or wrong knowledge of iron and iron-rich foods (e.g., stating plantain as being rich in iron), most of the participants were able to name iron-rich foods. The most common responses were cocoyam leaves (*kontomire*), turkey berries, beans, fish and groundnut. When asked more specifically about iron-deficiency anemia, women described their doctor's recommendations on how to treat it. These included: increasing their consumption of green leafy vegetables (mainly *kontomire*) and turkey berry as well as mixing turkey berry into their Milo (Nestle® chocolate drink). Only one respondent mentioned increasing their meat consumption. A few participants highlighted the importance they give to their doctors' recommendations, stating that if doctors were to ever discourage the consumption of *akokono*, they would stop eating it: "*It will only take a medical advice from a doctor to stop me from eating them" (Community B).* We noticed that respondents held some wrongful beliefs and myths about nutrition and healthy cooking approaches. Those included reducing the use of pepper and spices and substituting vegetable oil with palm oil. Though reducing pepper and spices are not harmful to one's health, those wrongful assumptions raise concerns about other possible myths that could negatively impact women's health. For instance, though the negative

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effects of palm oil consumption have been contested, two meta-analyses conducted in developed and developing countries found a significant relationship between an increased palm oil consumption and higher ischemic heart disease mortality rates (Chen, Seligman, Farquhar, & Goldhaber-Fiebert, 2011; Sun et al., 2015). In addition, doctors' recommendations to alleviate iron-deficiency anemia appeared to be incomplete. They advised anemic patients to include turkey berries and cocoyam (*kontomire*) in their diets as these are good sources of iron (Akoto, Borquaye, Howard, & Konwuruk, 2015; Amagloh & Nyarko, 2012; Wada, Feyissa, & Tesfaye, 2019); however, *in vivo* studies have shown that turkey berry and cocoyam have poor iron bioavailability due to their high content of anti-nutritional factors (such as phytates, oxalates). Their consumption is therefore not very effective in combating iron-deficiency unless consumed with non-heme iron absorption enhancers such as Vitamin C, which doctors did not promote (Agbemafle, Hanson, Bries, & Reddy, 2019). This finding highlights once again the importance of nutrition education and health literacy about iron, iron-deficiency anemia and nutrition among Ghanaian women and health practitioners.

The current study had some weaknesses. Due to the COVID-19 pandemic, we could not reach as many participants as we had initially planned for; however, we were able to reach the point of data saturation with the number of focus groups conducted. In addition, a community that was initially interested in participating dropped out from the study during data collection due to having experienced "helicopter researcher" with another researcher working on *akokono and* associated us with them. This loss was unfortunate as we could have benefited from this community's residents' knowledge. This study, however, has many strengths: 1) dividing the communities based on their access to palm trees allowed to detect a lack of differences in perceptions between both groups; 2) conducting focus groups where women felt open to share

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their experiences and knowledge on *akokono,* food preparation and nutrition; 3) inquiring about sensitive topics such iron-deficiency anemia.

3.4 Conclusion

This study found that women generally viewed palm weevil larvae as a tasty and nutritious food and were mostly in favor of its processing (freezing, product-development) as a means to increase its availability and accessibility. Scarcity, unhygienic conditions, and mistrust were perceived as major barriers to palm weevil larvae consumption. Some barriers could be overcome through adequate nutrition education pertaining to the importance of iron, the dangers of anemia and the benefits of palm weevil larvae. The need for nutrition education is all the more important as doctors' nutrition-related recommendations to alleviate iron-deficiency anemia seemed incomplete and misleading. Women's interest in palm weevil larvae and involvement in household food purchasing and preparation make palm weevil larvae's domestication a promising strategy to increase its access and consumption among Ghanaian women and their families. This strategy, if proven successful, could also increase dietary diversity and livelihood options for Ghanaian women, as well as overcome their fears of food unsafety and insalubrity.

Further investigation of the logistics and costs associated with the domestication of palm weevil larvae should be conducted. In addition, future studies should quantify the frequency and use of palm weevil larvae while focusing on its contribution to the total iron consumed in Ghanaian women's diets.

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Bridge Statement 1

The first study in this thesis sought to gain insight into Ghanaian women's acceptance of palm weevil larvae for purchase and consumption, as well as identify the facilitators and barriers to its use through focus groups discussions and mind mapping in selected peri-urban communities in the Ashanti region. Findings showed that women had a strong interest and desire to consume *akokono* should it be made more accessible to them. Since access was identified as the most important barrier to women's consumption of *akokono*, the second study aimed to investigate the factors that influenced women's access to *akokono* through evaluating its marketability, as well as to identify strategies that provide ideal entry points into expanding its consumption in Ghana. Marketability was used as a proxy for accessibility since increase access to food could be achieved through sale.

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CHAPTER 4: MANUSCRIPT 2

Identifying factors and strategies to increase the accessibility and marketability of palm weevil larvae in Kumasi, Ghana

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Manuscript to be submitted

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Abstract

For Ghanaian women of reproductive age (WRA), anemia remains a pressing issue, currently affecting 35% of this population according to the most recent "State of Food Security and Nutrition in the World" report, and is mostly associated with iron deficiency. Though increasing the consumption of animal source foods (ASF) is recommended to curtail iron-deficiency anemia, this strategy is not the most cost-effective or environmentally friendly. As an alternative approach, palm weevil larvae could be leveraged to improve WRA's iron status through direct consumption and sale of the larvae. The factors influencing women's propensity to consume *akokono* have already been studied in Ghana; however, those affecting its sale and marketability have not. As a result, the objective of this study was to identify the factors influencing the marketability to palm weevil larvae in Kumasi. A semi-structured survey and key-informant in-depth interviews were conducted among sellers and customers of palm weevil larvae in Kumasi. A total of 97 customers and two key informants from Akokono House were interviewed. The survey assessed the reasons for purchasing *akokono*, types of *akokono* products purchased, purchasing location, and customers' perceptions about its affordability. Qualitative data were analyzed using an inductive thematic approach. Cross-tabulations and chi-square analyses were completed for the following variables: socio-economic and demographic, purchasing frequency of customers, travel time, and means of transportation. Along palm weevil larvae's value chain and within customers' food environment, several factors act as facilitators and barriers to its marketability. These factors include customers' trust and familiarity with palm weevil larvae's origin, food literacy, awareness of and access to palm weevil larvae purchasing locations, and factors pertaining to palm weevil larvae's characteristics, such as its taste, quality, price, shelf-stability, and product diversity. Raising awareness on palm weevil larvae's benefits, farming,

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purchasing locations, and cooking techniques is crucial. In addition, palm weevil larvae's challenging access supports the need for its domestication in households and communities. Ghanaian authorities should foster financial support and equipment to increase female farmers' capacity to domesticate palm weevil larvae for consumption and sale purposes.

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4.1 Introduction

Anemia is a pressing issue in Ghana affecting over 35% of women in 2019, according to the most recent "State of Food Security and Nutrition in the World" report (FAO, 2021). In Ghana, reduced dietary diversity and inadequate iron intake are among the major factors associated with anemia in women of reproductive age (WRA) (Annan et al., 2021; Petry et al., 2021; Wun et al., 2016). Increasing the consumption of animal-source foods (ASF) such as poultry and beef could help curtail iron deficiency. In rural areas, however, ASF are not always available or affordable. Neglected and underutilized species (NUS) such as palm weevil larvae that are nutritious, economically viable, locally available, adaptable, and environmentally friendly could instead substitute the usual ASF in improving dietary diversity and increasing iron intake (Xuan Li & Siddique, 2018). In addition to being good sources of protein and iron, palm weevil larvae have a low environmental footprint and can be farmed and domesticated with minimal resources, making them sustainable alternatives (Hanboonsong et al., 2013).

As a result, palm weevil larvae could be leveraged to positively impact the iron status of WRA through a combination of three principal pathways: 1) direct consumption through either household production of palm weevil larvae or purchase from markets; 2) income generation by direct sale of palm weevil larvae (or by indirectly partaking in the palm weevil value chain) to increase the ability to purchase iron-rich foods such as poultry and beef; 3) increased commercial production of palm weevil larvae which would result in reduced market prices, thus making it more accessible to purchase for consumption (Arimond et al., 2010). Looking at these pathways would allow to explore the different stakeholders and processes involved in the palm weevil larvae value chain. To our knowledge, no study has done that before.

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This current study sought to: 1) investigate the factors influencing palm weevil larvae's marketability and accessibility in Ghana, and 2) identify strategies that provide ideal entry points into expanding palm weevil larvae consumption in Ghana.

4.2 Methodology

4.2.1 Study design

A survey and key informant in-depth interviews were administered throughout December 2020 – February 2021 to collect primary data. Verbal approval and consent were obtained from the respondents prior to the data collection. The surveys and interviews aimed at enhancing our understanding about the existing palm weevil larvae sale and marketing system, and its key challenges and facilitators.

4.2.2 Sampling sites and sample size

In-depth interview participants were selected purposefully using a multi-stage sampling approach. First, a list of recognized *akokono* seller companies established in Ghana for over six months was compiled. Then, employees who were in charge of *akokono*'s sale and marketing were informed about the study and invited to participate to the in-depth interviews.

Survey participants were selected using a purposeful sampling approach whereby every customer purchasing *akokono* from specified markets were invited to take the survey (granted they had not taken it before). A sample size of 80 participants was selected based on an estimated weekly population size of 86 customers (assessed by Akokono House, a major *akokono* selling

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company in Ghana). Due to the small population size, every customer aged 18 years and older was invited to participate in the study, until at least 80 participants had been surveyed.

4.2.3 Data collection

Prior to data collection, institutional review board approval was received from McGill University's Research Ethics Board (file # 20-01-032) and Kwame Nkrumah University of Science and Technology (KNUST)'s Committee on Human Research, Publication and Ethics.

4.2.3.1 Key informant in-depth interviews

Key informants provided insights on the facilitators and barriers to palm weevil larvae's sale and marketing in Ghana. Results from the first stage of our sampling approach revealed that Akokono House was the only known seller of *akokono* in Ghana. Employees in charge of the sale and marketing of *akokono* at Akokono House were therefore selected as key informants. These employees included the CEO and founder of Akokono House, and the sale manager who both had over five years' experience in the field. These interviews were performed via Zoom and were audio-recorded. Written consent was obtained from both participants.

4.2.3.2 Survey design and administration

Our structured survey was developed and adapted from a study conducted in 1994 by Head and his colleagues that aimed to assess the marketability of Saltwater-Cultured Florida Red Tilapia in Puerto Rico (Head, Zerbi, & Watanabe, 2007). The survey questionnaire was designed in English using LimeSurvey which is an online survey tool supporting a large variety of question formats and statistical results reports, and subsequently translated into Twi. Our survey

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was first pre-tested by KNUST professors and field staff to test for content validity, then piloted in a neighboring community to test for face validity and readability.

The survey was administered over a two-week period at Akokono House's farmgate market and several markets in the Kumasi region in Ghana by trained research assistants to accommodate for illiterate participants. The survey's aim was to collect information on the factors influencing customers' willingness to purchase *akokono* and their thoughts on *akokono* and *akokono*-based food products.

The survey included multiple-choice, dichotomous, and open-ended questions. Some questions referred to the respondents' socioeconomic and demographic information, while others inquired about respondents' general *akokono* consumption and purchasing habits, as well as their physical and economic access to *akokono*.

4.2.4 Data analysis

The completed survey responses were exported from LimeSurvey to SPSS (version 24). Data were analyzed using SPSS (version 24) and Lime Survey's statistical features. Mean scores were calculated for numerical data while socio-demographic and *akokono* consumption habits data were expressed in frequency and percentage distributions. The chi-square test was used to determine an association between customers' purchasing frequency and selected sociodemographic categorical variables. When the cells' expected count was higher than 20%, the likelihood ratio was used instead. The in-depth interviews were transcribed and coded in MAXQDA (version 24) using an inductive thematic analysis approach.

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4.3 Results and Discussion

4.3.1 Socio-economic background of survey respondents

A total of 97 responses were collected both from Akokono House's farmgate location (n=49) and field markets in the Kumasi area (n=48). The age of the respondents ranged from 18 to over 50 years old with 89% men (96% and 81% male respondents from farmgate and field, respectively). Most customers from the farmgate and field markets fell between ages 35-44 and 25-34, respectively (Table 4.1). Farmgate customers were found to be higher income earners than customers from the field, with over 53% of the former earning more than 2000 Ghanaian Cedis per month as compared to over 80% of customers from the field earning less than 2000 Ghanaian Cedis (Table 4.1). Although most of the respondents had some level of education, customers from the farmgate market seemed to have higher educational attainment (over 50% had a 1st cycle university degree) than customers from the field markets. Over 54% and 76% of all surveyed women and men, respectively, had at least a secondary education (Table 4.1). Finally, most respondents from both farmgate and field markets (61.2% and 79.1%, respectively) were Asante people (natives of the Ashanti region in Ghana). At the farmgate market, the second largest groups were Ga (10.2%) followed by the Akan and the Akyem (6.12%, respectively) while in the field markets, those were Nigerians (6.25%). Other ethnic groups represented in the sample (<5%) were the following: Bono, Fante, Wale, Goan, Gyenkyereni, Sefwi, Kwahu, Ebuom, Nzema, Baafera.

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Table 4.1 Socioeconomic and demographic characteristics of respondents

	Proportion of respondents based on market location	
	Farmgate market (%)	**Field markets (%)**
Age (years)		
18-24	4.08	8.33
25-34	20.4	29.1
35-44	38.7	22.9
45-49	8.16	16.6
50+	28.5	22.9
Gender		
Women	4.08	18.7
Men	95.9	81.2
Education level		
No degree	0.00	8.33
Primary school	6.12	37.5
Secondary school	40.8	45.8
University degree 1st cycle	42.8	8.33
University degree 2nd-3rd cycles	10.2	0.00
Income level (GHC/month)		
Below 500	6.3	10.6
500 to 2000	40.7	70.7
2001 to 5000	34.7	10.4
Over 5000	18.3	8.3

4.3.2 *Akokono* purchasing habits of respondents

While fried *akokono* was the most popular form in field markets (75%), the kebab skewer (51%) composed of five to six pieces of grilled *akokono* and the raw form (31%) were the most

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popular among farmgate customers. Among the other forms purchased, participants also mentioned *akokono*-shito, an oily pepper sauce added to a variety of Ghanaian dishes.

Most respondents from the farmgate (71%) and field (77%) markets were occasional purchasers of *akokono*, buying *akokono* less than once a month. The reasons for purchasing the *akokono* were mainly associated with participants' cultural food habits (63% of farmgate and 75% of field respondents). In addition, dietary and health reasons appear to be a particularly important incentive for farmgate customers (43%) to purchase *akokono*. While *akokono's* taste encouraged over 20% of field respondents to purchase it, it was not the main motivator for farmgate customers (2%).

Table 4.2 Akokono purchasing habits of respondents

	Proportion of respondents based on market location	
	Farmgate (%)	**Field (%)**
Type of *akokono* customer		
New*	20.4	8.3
Regular	79.6	91.7
Purchase frequency		
Daily	2.00	10.4
Weekly**	16.3	10.4
Monthly ***	10.3	2.10
Occasionally****	71.4	77.1
Forms purchased		
Fried	16.3	75.0
Kebabs	51.0	10.4
Raw	30.6	16.7
Ground	2.00	0.00
Cookies	2.00	0.00

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Other	12.2	4.2

*: New indicating that it is their first time eating it
** Weekly: once to three times a week
*** Monthly: once to three times a month
**** Occasionally: less than once a month

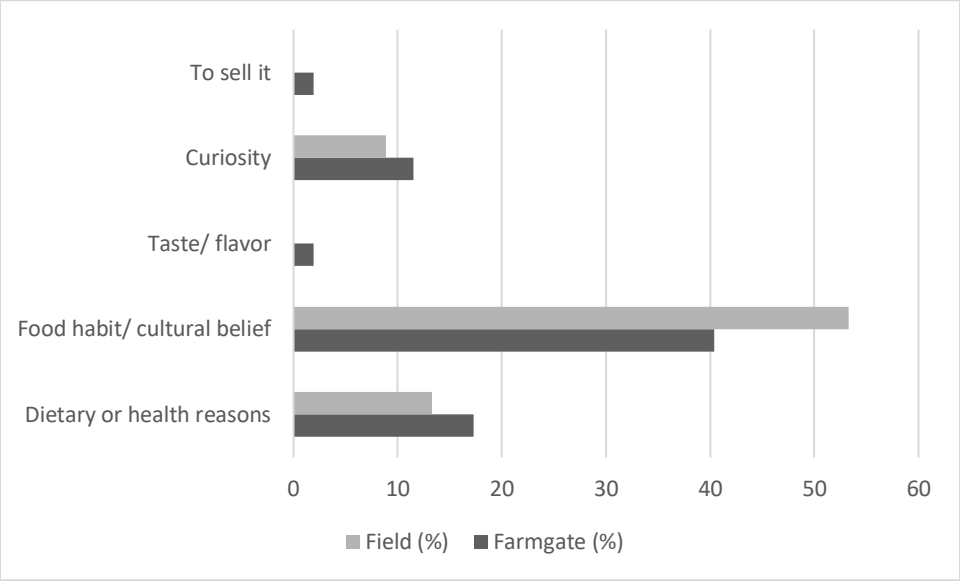

Figure 4.1 Reasons for purchasing akokono for farmgate and field market customers

4.3.3 Purchasing location, travel time to purchasing location and means of transportation of customers

While customers prioritized their own cars as their principal means of transportation to Akokono House's farmgate market (59%) followed by public transportation (22%), the majority of field respondents used public transportation as their main means of transport to the field markets (88%) as seen in Figure 4.3.

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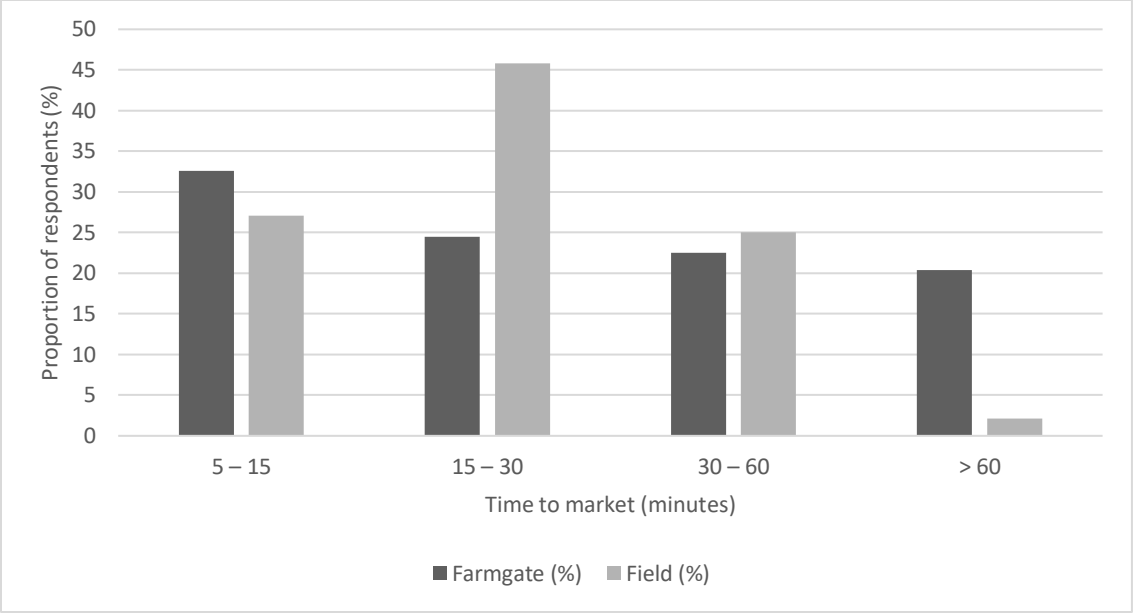

Figure 4.2 Transit time for farmgate and field market customers

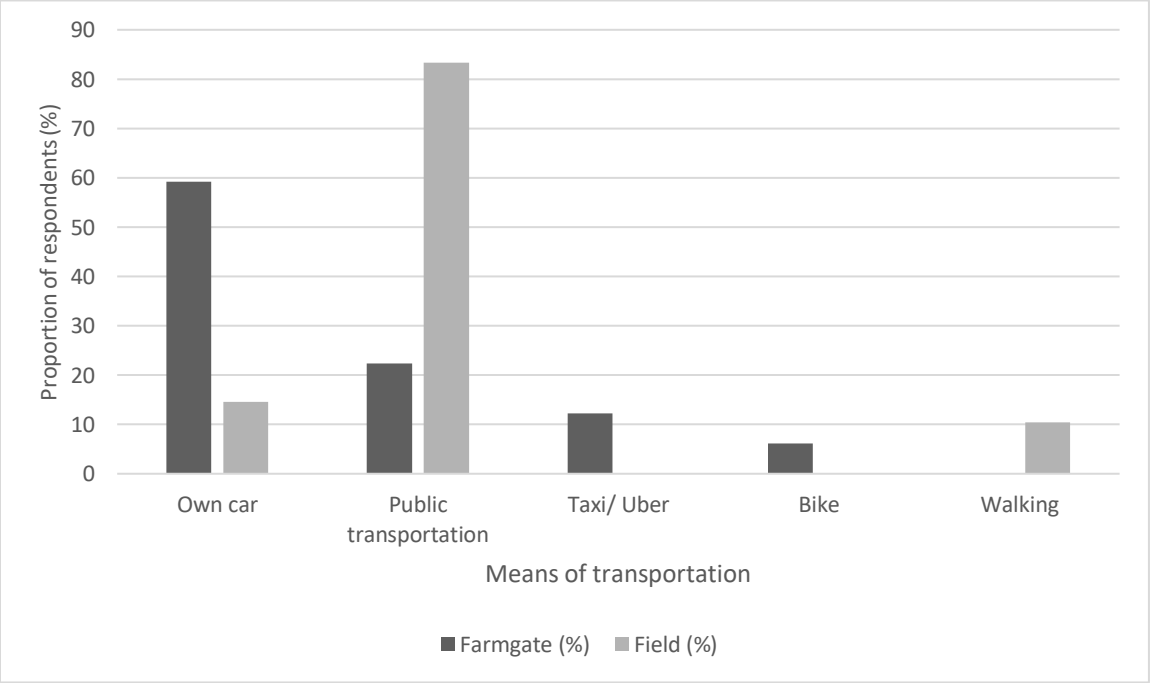

Figure 4.3 Means of transportation for farmgate and field market customers

Customers who purchased *akokono* exclusively from Akokono House's farmgate market did so because it is convenient and accessible (16%), reliable and consistent (16%), and the only

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seller of *akokono* they know of (57%). On the other hand, customers interviewed at field markets rarely bought their *akokono* from Akokono House's farmgate (6%). Instead, they purchased it from markets they worked at from Akokono House's representatives (97%) due to being unaware of other *akokono* sellers. The most popular field markets were Adum Market, Kejetia, Magazine and Mbrom markets located at 9 kms, 9 kms, 13 kms and 11 kms respectively from Akokono House's farmgate.

Out of all respondents, 21% spent 15-30 minutes in public transportation to get to the markets, followed by 15% reaching markets within 30 to 60 minutes using public transportation. Very few participants walked to the markets; and the few who did (3.1%) needed 5 to 30 minutes to reach the markets. Customers who took less than five minutes to reach markets used cars as their principal means of transportation (50%), followed by taxis (25%) and both cars and walking (25%). Over 11% of all respondents spent over an hour on the road to reach markets, while most customers (35%) spent 15-30 minutes to reach the markets followed by 26% who took 30-50 minutes, meaning that over 70% of respondents needed at least 15 minutes to get to the markets.

4.3.4 Customers' perceptions about the affordability of *akokono*

Most respondents found *akokono* affordable (71% of farmgate customers and 60% of field customers). Those who did not were asked to comment on the current price and suggest one they would deem acceptable. Results showed that overall, customers were willing to pay almost half of *akokono's* market price, or up to 1 GHC per skewer and 15-30 GHC per kilogram.

4.3.5 Factors influencing the purchase of *akokono* in Ghana

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Most respondents from farmgate (40.4%) and field markets (53.3%) were motivated to purchase *akokono* for its cultural value. “Health and nutritional reasons” (17.3% and 13.3% in farmgate and field markets, respectively) were perceived as the second most important motivator followed by “being curious to try a new product” (11.5% and 8.90% in farmgate and field markets, respectively).

We were interested in finding whether an association existed between customers’ *akokono* purchasing frequency and selected socio-economic and demographic variables (age, gender, educational attainment, and income level). According to the results in Table 4.3, gender (χ^2=15, p=0.05) and educational attainment (χ^2=32, p<0.03) were significantly associated with customers’ purchasing frequency. In other words, men and respondents with higher educational degrees purchased *akokono* more frequently than women or respondents with lower educational degrees. The majority of participants purchasing *akokono* on daily, weekly, monthly, and occasional bases were men (67%, 85%, 100% and 91%, respectively). In addition, out of the daily buyers, 33% of them had no education and 33% had primary education. Out of the daily, weekly, monthly, and occasional buyers, 17%, 23%, 84% and 29%, respectively, had university degrees and very few respondents were uneducated. Although women dominate in the sale of palm weevil larvae, customers were predominantly men. Gender roles have a strong influence on personal food environments. Our previous manuscript demonstrated that within our selected communities, women were primarily responsible for food preparation for their households but were influenced by their husbands and their income generation (Global Alliance for Improved Nutrition, 2020).

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Table 4.3 Crosstabulations between purchasing frequency and selected categorical variables

	Likelihood ratio Chi-Square value	Degrees of freedom	Significance (2-sided)
Age group	19	12	0.5
Gender	15	3	0.05
Educational attainment	32	12	0.038
Income level	30	20	0.17

Table 4.4 Respondents distributions for gender and educational attainment within purchasing frequencies

	Daily (%)	Weekly (%)	Monthly (%)	Occasionally (%)
Gender				
Women	33	15	0	10
Men	67	85	100	91
Educational attainment				
No education	33	0	0	3
Primary education	33	8	0	25
Secondary education	17	69	17	43
University (1st cycle)	17	15	67	25
University (2nd-3rd cycles)	0	8	17	4

%: within purchasing frequency

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4.3.6 Facilitators and barriers for the marketability of *akokono* from seller's perspective

Facilitator 1: Diversifying and expanding distribution channels

Respondents noted that diversifying and expanding their distribution channels drove their outreach expansion and sale of *akokono.* Putting in place delivery systems has proven efficient in reaching more customers especially during a pandemic:

> *"... We decided to get a motor bike to do deliveries to people in their homes. Now we realized that most of our customers were home. We looked at how we could distribute it to our customers at a very affordable price and at their convenience."*

Respondents noted how helpful the addition of a middleman was in the distribution scheme to increase the awareness and outreach of *akokono* locally and internationally.

> *"We are looking to get a lot of these distributors in locations where our customers are heavily located."*

Facilitator 2: Product diversification

Akokono House sells a wider range of products and services including stir fried *akokono*, frozen *akokono,* kebabs, cookies, full meals, dried *akokono*, shito, and food service. This diversification is important as it allows to cater to different needs. Some customers showed preference for raw *akokono* as it gave them the freedom to experiment with its cooking; while others preferred buying it cooked or processed due to being unaware of how to prepare it (lack of food literacy).

Processing and developing *akokono*-based products is necessary to increase the demand for *akokono* and drive the transformation of agriculture and food systems to benefit consumers, farmers, and other *akokono* value chain actors (X. Li & Siddique, 2020). Processing *akokono*

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into more shelf-stable products could increase its accessibility to remote communities and its convenience, as well as expand its distribution outreach.

One of the main barriers of *akokono's* production and processing is the lack of/ limited knowledge regarding its safety concerns. Studies have revealed the existence of food safety hazards (chemical, biological and allergens) in edible insects stating that their prevalence and concentration in insects and insect-based foods are majorly influenced by the feed substrate on which insects are reared (Imathiu, 2020; Arnold van Huis, 2021). According to a study conducted in Nigeria, palm weevil larvae could be poisonous if not handled properly during collection, processing and post-processing (C. Ebenebe & Okpoko, 2016); however, no analysis has been conducted for palm weevil larvae in Ghana, where production and processing conditions might be different.

Facilitator 3: Marketing and advertising/ educating

Marketing *akokono* and educating customers about its existence and benefits is crucial to increase its demand and marketability. Respondents recognized education as an important tool to familiarize customers with *akokono* and its important value in the Ghanaian culture.

Sale strategies are at the core of the food environment and constitute an interface between the *akokono* supply chain (production, processing, storage and distribution) and households' or individuals' acquisition and consumption of *akokono* (Global Alliance for Improved Nutrition, 2020). As a result, the sale of palm weevil larvae is influenced by external and internal factors of the food environment. The former includes factors affecting the seller, such as the price, availability of palm weevils and the marketing strategies while the latter pertain to the customer and include their accessibility to the markets, affordability, convenience, and acceptability of the

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products. The marketing conducted in the study area was done through radio adverts, social media promotions and branding (mostly clothes) and influenced customers' food preferences, desires, knowledge and choices (Turner et al., 2018).

Barrier 1: Limited physical access

The major barrier identified was the limited physical access to *akokono*:

"There are people who already want our product. We don't need to convince them of anything. The problem is accessing them"(Akokono House sale director).

Our study indicated that customers needed to travel at least 15 minutes (either by personal car or public transportation) to reach markets that sell *akokono.* Markets' distance and connection to key points in the city are crucial aspects. If markets are far or hard to reach, customers will be less inclined to buy *akokono*. In this case, it could be easier for them to domesticate *akokono* rather than purchase it. Akokono House's employees were aware of customers' travel distance being a barrier to *akokono*'s marketability. On the other hand, in certain cases, customers were willing to travel far because of their skepticism:

"They tell us that they heard about us and they wanted to come and see how big our farm is and if we are really serious"

and their curiosity and intrigue in other cases:

"... So they come they buy and you realize that they are coming from very far but don't mind because they are very intrigued by the product"

Expanding field markets' outreach is a challenging approach due to financial limitations that restrict sales associates from reaching more markets and farther areas:

"... we are a bit limited in our resources when it comes to transportation, so if they know that there is a lot of traffic at Abrepo junction, which is quite far, which they will have to spend roughly 10 Ghanaian Cedis to get to the place and back; meanwhile what they are given is less than that, they would rather

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look at areas that the transportation and resources would be enough and they would still have the customers and target audience to sell to"(Akokono House Sale Manager)

An approach that could potentially increase access to *akokono* is semi-cultivation, whereby the palm weevil is partially raised in captivity where its habitat is modified to increase production yield without separating it from their its populations. Semi-cultivation is a more feasible strategy for communities that have access to palm trees, as this system requires either to directly harvest the palm weevils, or to cut palm trees to trigger egg laying by palm weevils which would then be harvested at their larval stage (Baiano, 2020). From a financial standpoint solely, the semi-cultivation of palm weevil larvae could be a profitable venture for women granted that adequate start-up funding, training and equipment are provided (Commander et al., 2019). In addition, for women to manage to sell palm weevil larvae at markets and have enough for their own household consumption, those would need to be produced in very large quantities, which would require, in addition to building women's capacity, adequate infrastructures and resources to sustain this system.

Barrier 2: Value chain: post-harvest handling, storage, and packaging

Post-harvest handling and storage were important challenges that were not foreseen by the respondents. Fresh *akokono* have a shelf-life of less than 48 hours. Respondents recognized that within and beyond this time limit, *akokono* start to die or lose weight. Due to fresh *akokono's* very short shelf life, finding proper preservation, packaging and transportation techniques is crucial. Freezing is a popular method to increase a product's shelf-life. For *akokono*, however, this method came with two challenges: finding a cost-effective way to transport the frozen product, and preventing quality deterioration of the thawed product.

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Palm weevil larvae's low shelf-life (less than 48 hours for raw palm weevil larvae) and high perishability are associated with its high fat content making it susceptible to lipid oxidation and rancidity. This limitation affects the distribution and restricts the sales' outreach. Product diversification could overcome this barrier as other forms of *akokono* (such as ground, fried, shito, or cookies) require simpler storage conditions; however, extensive research is needed to find alternative strategies to extend raw *akokono*'s shelf-life.

Barrier 3: Price point

Respondents recognized that *akokono's* price-point was on the higher-end side when compared to other protein-rich commodities, making it not as accessible to all Ghanaians. When comparing *akokono's* nutritional value and weight of edible matter to other protein-rich commodities, however, *akokono's* price becomes more reasonable:

> *"...people are ok spending 35 Ghanaian Cedis on a chicken which once they remove the feathers, the skins, the bones, the carcass, they're not left with more than 700 g of edible mass. While our product is 40 Ghanaian Cedis / kg but from a caloric perspective it is a much better bargain- you're getting more fat. From a micronutrient perspective, it has iron, vitamin B12."*

Respondents recognized that when purchasing a commodity, customers compare its price to its volume rather than to the level of satiety it imparts or the calories it provides. As a result, it becomes crucial to educate customers on these matters to promote *akokono* as a protein-rich food commodity and justify its price:

> *"...a challenge has been driving home the price to value so in that context it does help. For ex, if somebody says the product is expensive, we'll say, oh yeah but you'll be full until dinner because it is really filling, it has protein and fat."*

Barrier 4: Lack of education and knowledge

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The lack of extensive scientific knowledge on *akokono's* microbial safety, quality deterioration, and the approaches needed to mitigate and prevent these issues is halting some of the progress with increasing the marketability of *akokono* in Ghana:

> *"...So, if a farmer were to ask me "what are all the diseases the akokono could die from", well we don't know, as in the science community, we don't know yet."*

In addition, one of the key advantages of consuming *akokono* is its nutritional benefits and low carbon footprint. Respondents recognize, however, that since customers are not aware of these benefits, they are not as inclined to look for *akokono*.

Barrier 5: Customer acceptance

For the economic, social, nutritional, and environmental benefits of *akokono* to be realized, consumers must accept it. Several factors which were identified in our study play a role in influencing customers' acceptance of *akokono* and include: *akokono* (or *akokono*-based products)'s price, quality and taste, convenience, diversity, nutritional composition, and customers' confidence in the product. These findings corroborate the ones from a study conducted in Kenya which assessed the factors responsible for consumer acceptance of edible insects and found that price, quality, benefits and risks of the product, convenience, social trusts and norms, and prior attitude all influenced consumers' acceptance of edible insects (Pambo, Okello, Mbeche, & Kinyuru, 2016).

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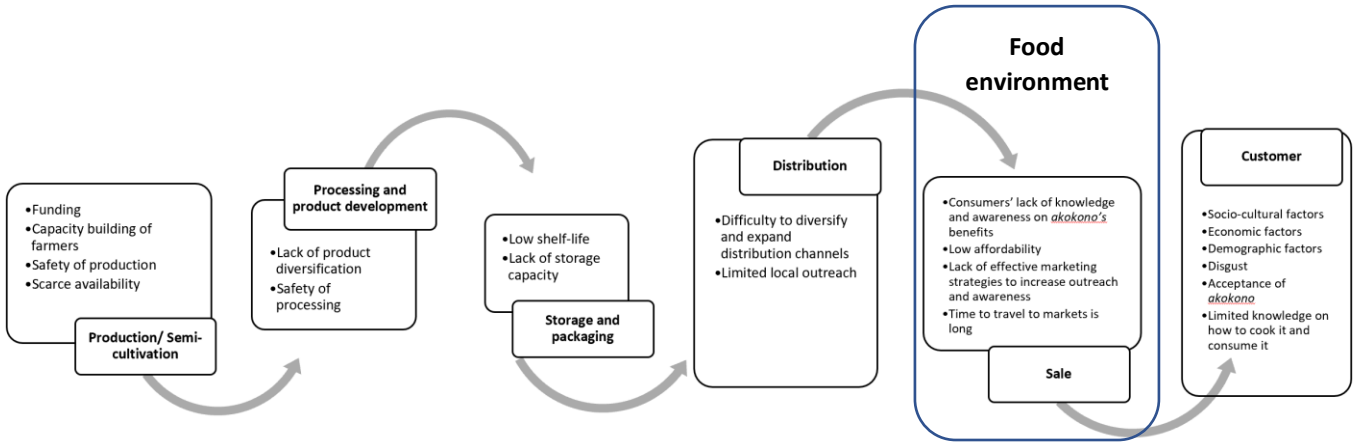

Figure 4.34 Factors along palm weevil larvae's value chain influencing its marketability

4.4 Conclusion and recommendations

This study identified key factors affecting the accessibility and marketability of palm weevil larvae from both sellers' and customers' standpoints. These factors pertained to palm weevil larvae's value chain and to customers' food environment. Domesticating palm weevil larvae and building the capacity of women farmers within communities appears to be the most crucial driver in expanding palm weevil larvae's sale outreach and consumption in Ghana. In addition, continued research and food product development are required to increase palm weevil larvae's acceptance among Ghanaians and convenience for customers.

To overcome the identified challenges, a few recommended strategies are described in Table 4.5.

Table 4.5 Recommend strategies to overcome akokono's key marketability challenges

Key challenges	**Recommended strategies**
Safety concerns in the production and processing of *akokono*	• Using spices like garlic and Negro pepper which have anti-microbial properties in the preparation of roasted *akokono* could be useful in controlling bacterial contamination (C. Ebenebe & Okpoko, 2016).

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	• Applying hygienic procedures like washing, roasting, salting and the use of preservatives during processing. • Developing standards for labelling, packaging and certification of palm weevil larvae products in Ghana.
Funding and capacity building for community domestication of *akokono*	• Including palm weevil larvae-based interventions in Ghana's National Nutrition policy and other governmental policies aiming at supporting livelihood programmes to increase women's economic autonomy. • Subsidizing training by palm weevil larvae farmers and basic equipment (bowls, nets, feed) for the domestication of palm weevil larvae within communities. • Building the capacity of women farmers and traders on palm weevil larvae domestication and processing.
Shelf-stability and quality deterioration of *akokono*	• Using refrigerated trucks for distribution (costly). • Using modified-atmosphere-packaging (costly). • Developing canned palm weevil larvae-based food products. • Government encouraging and facilitating collaboration with research institutions and NGOs to support food product development and food quality/ safety research.
Accessibility	• Expanding distribution channels (internationally, nationally and within regions) • Diversifying distribution channels (through middlemen and cold stores)
Affordability	• Increasing demand for palm weevil larvae to decrease cost of production.

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	• Educating consumers on the notions of "price per weight of edible matter" and "price per nutritional value" as a price comparison technique.
Acceptability of *akokono* and *akokono*-based products	• Educating consumers on *akokono*'s nutritional and environmental benefits by public health workers and Ghana's Ministry of Agriculture, Health and Environment. • Teaching consumers how to cook and prepare *akokono*-based nutritious meals. • Conducting sensory evaluation to evaluate the acceptability of *akokono*-based products as well as develop products that will fit communities' needs and likings.

4.5 Acknowledgement

I would like thank Esi Aduku, Charles, Theresa, and Godwin for their unwavering assistance in the field in administering the marketability surveys.

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Bridge Statement 2

Results from Chapters 3 and 4 illustrated communities' desire to consume, purchase, and sell *akokono.* I evaluated the factors influencing customers' access to palm weevil larvae and suggested recommendations to increase it. One of the strategies suggested to increase access and consumption of palm weevil larvae is to incorporate them into a commonly consumed and widely available staple Ghanaian food product. Consequently, the third study aimed to explore Ghanaians' acceptance of varying fortification levels of palm weevil larvae-tomato paste and to investigate the main determinants for consumers' willingness to pay for the product.

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CHAPTER 5: MANUSCRIPT 3

Nutritional composition and consumer acceptance of tomato paste and tomato sauce samples fortified with palm weevil larvae (*Rhynchophorus phoenicis Fabricius)* in the Ashanti region, Ghana

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Manuscript to be submitted to the Food Science and Nutrition Journal

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Abstract

Edible insects, such as palm weevil larvae, have been promoted as an alternative source of nutrients in developing countries for their nutritional benefits, cost-effective rearing, and yearly availability. Unfortunately, consumer acceptance remains a barrier to their utilization. A supplemental palm weevil larvae and tomato paste was developed as part of efforts to understand whether incorporating edible insects into staple foods could help overcome this barrier. Palm weevil larvae flour and tomato paste were mixed in three formulations that had 8, 15, and 30% of palm weevil larvae flour. Samples were subjected to proximate and mineral content analyses and sensory evaluation. Proximate and mineral composition of the tomato paste increased with increasing levels of palm weevil larvae flour. Among the blends, tomato paste containing 30% palm weevil larvae had the highest protein, fat, and total solids content as compared to unfortified tomato paste. Zinc levels also increased with increasing levels of palm weevil larvae flour. Carbohydrate and crude fiber concentrations of the samples, however, decreased with increasing fortification levels. As for the iron content, no significant increase was observed. The overall acceptance and willingness to purchase fortified tomato paste as determined by sensory evaluation using women of reproductive age was high for all samples and increased with increasing knowledge about palm weevil larvae's nutritional benefits. Overall acceptance and willingness to purchase fortified tomato paste were significantly dependent on the samples' color and consumers' overall liking of the products. Adding palm weevil larvae to tomato paste did not provide a significant source of iron for women in Ghana.

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5.1 Introduction

Iron deficiency anemia remains a globally prevalent threat to women's health. In 2019, around 30% of women of reproductive age (WRA) were estimated to be anemic worldwide (Ritchie & Roser, 2017). Moreover, in Ghana, anemia affected over 35% of WRA in 2019 and 40% of the cases were attributed to iron deficiency (Safiri et al., 2021).

Various strategies have been promoted as effective ways in reducing iron deficiency anemia at population level including food fortification and iron supplementation. In Ghana, however, their implementation has not proven successful due to inadequate and inconsistent fortification across the country, inequitable distribution of supplements and/or low adherence to supplementation (Appiah et al., 2020; Nasir et al., 2020; S. J. M. Osendarp et al., 2018). To overcome such challenges, food-to-food fortification is suggested as a complementary strategy that utilizes locally found underutilized animal or plant-based micronutrient-rich sources to fortify nutritious, affordable, locally available, accessible and acceptable food vehicles, commonly consumed by the population (Chadare et al., 2019). Evidence on the effectiveness of food-to-food fortification has been reported in the literature, particularly for increasing iron content and bioavailability. A recent review assessed the impact of fortifying starchy staple foods with vegetables, fruits, and animal products at levels varying between 10% and 50% on the iron content and *in vitro* iron bioavailability. Results from this review indicated an average increase of 50% in the fortified foods' iron content, as well as a significant increase in the iron's *in vitro* bioavailability (Kruger, Taylor, Ferruzzi, & Debelo, 2020). Of all the studies assessed, one was of particular interest to this research as it evaluated the impact of adding mopane worms to fermented cereals on its iron content and bioavailability (Gabaza, Shumoy, Muchuweti,

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Vandamme, & Raes, 2018). Results from this study indicated a significant increase in most of the selected cereals' iron content but no significant change in their iron bioavailability.

Edible insects are considered important food sources to improve the iron status of resource-limited populations owing to their nutritional value and cost-effective farming. Edible insects are rich sources of complete animal protein and contain essential vitamins and minerals (such as iron and zinc) in quantities comparable to those of beef. Edible insects' protein content ranges from 35% to 60% (dry weight), their iron content ranges from 4 milligrams to 62 milligrams per 100 grams of dry matter, and their zinc content ranges from 9 milligrams to 27 milligrams per 100 grams of dry matter (Gorbunova & Zakharov, 2021; Latunde-Dada et al., 2016; Mwangi et al., 2018). Insect consumption, or entomophagy, is practiced by over two billion people within 113 countries in Africa, Asia and Latin America (Arnold van Huis, 2021). In Ghana, the most commonly consumed insects are termites, shea tree caterpillar, grasshoppers, locust, field crickets and palm weevil larvae (*Rhynchophorus phoenicis Fabricius*) (J. Anankware et al., 2016). Palm weevil larvae, locally called *akokono*, are available all year long in palm-growing communities, and are particularly abundant during the rainy season from May to October (J. Anankware et al., 2016).

Despite the numerous benefits of edible insects, consumer acceptance remains a barrier to their utilization due to the disgust factor associated with their consumption (Imathiu, 2020). As such, to overcome this obstacle, incorporating edible insects into staple foods could promote their utilization as a food source and help reduce micronutrient deficiencies and malnutrition. For a successful fortification, the selection of the appropriate food vehicle, fortificant, and level of fortification is crucial. According to the Food and Agriculture Organization and the World Health Organization (Allen et al., 2006; Chadare et al., 2019), the food vehicle should be

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consumed frequently and in adequate quantities by the majority of the population, accessible financially and physically, and centrally processed. As for the fortificants, underutilized plant or animal species that are nutrient-rich and require little agricultural inputs are preferred. Finally, the fortification level should vary between 1% to 50% in such a way that the fortificant enhances the nutritional quality of the food vehicle without compromising its organoleptic properties or its acceptability by consumers.

Tomato paste was considered as a potential food vehicle to be fortified with palm weevil larvae. Tomatoes are a staple food in Ghanaians' diets and one the most widely consumed and produced fruits in Ghana (Ministry of Food and Agriculture (MoFA), 2020). Tomato consumption has increased from 280,000 tons in 2005 to more than 450 000 tons in 2013 (Food & Agriculture Organization of the United, 2019; Ministry of Food and Agriculture (MoFA), 2020; Van Asselt, Masias, & Kolavalli, 2018) and represents 40% of household vegetable expenditure (Van Asselt et al., 2018). Tomatoes are available all year long (Van Asselt et al., 2018) and constitute the base of several Ghanaian stews and dishes. Tomatoes are generally good sources of essential nutrients, though low in iron (Sainju, Dris, & Singh, 2003), and appear to have low levels of antinutrients including phytate, glycoside, saponin and tannin (Oyetayo & Ibitoye, 2012).

To evaluate the feasibility, effectiveness, and sustainability of this strategy, it is necessary to assess consumers' acceptability of the developed product and evaluate the nutritional changes imparted to tomato paste with the addition of *akokono* flour. To the best of our knowledge, no study has looked at consumer acceptance of palm weevil larvae-based tomato paste. Thus, the objective of this study was to explore Ghanaian consumers' acceptance of varying fortification

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levels of palm weevil larvae-tomato paste and sauce, and to investigate the main determinants for their willingness to pay (WTP) for the products.

5.2 Materials and methods

Using the Association of Official Analytical Chemists (AOAC) methods, we examined the nutritional composition of *akokono*-based tomato paste. A sample of 88 community men and women then conducted a sensory evaluation of six tomato paste samples with varying concentrations of *akokono* flour. Finally, these participants evaluated their acceptance and willingness to purchase the tested samples.

5.2.1 Raw materials

Samples of tomato paste and tomato sauce with varying palm weevil larvae compositions were prepared. The tomato sauce was prepared based on a local Ghanaian recipe. Full-fat palm weevil larvae flour was provided by Legendary Foods' farm site in Kumasi, Ghana. All the other ingredients were purchased from a local market in Kumasi, Ghana. The sensory evaluation was carried out in selected communities in Kumasi Ghana, while the analyses were performed in laboratories of the Department of Food Science at McGill University, Canada. All reagents used for the proximate and mineral analyses were obtained from Sigma Aldrich.

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5.2.2 Preparation of palm weevil larvae fortified tomato sauce

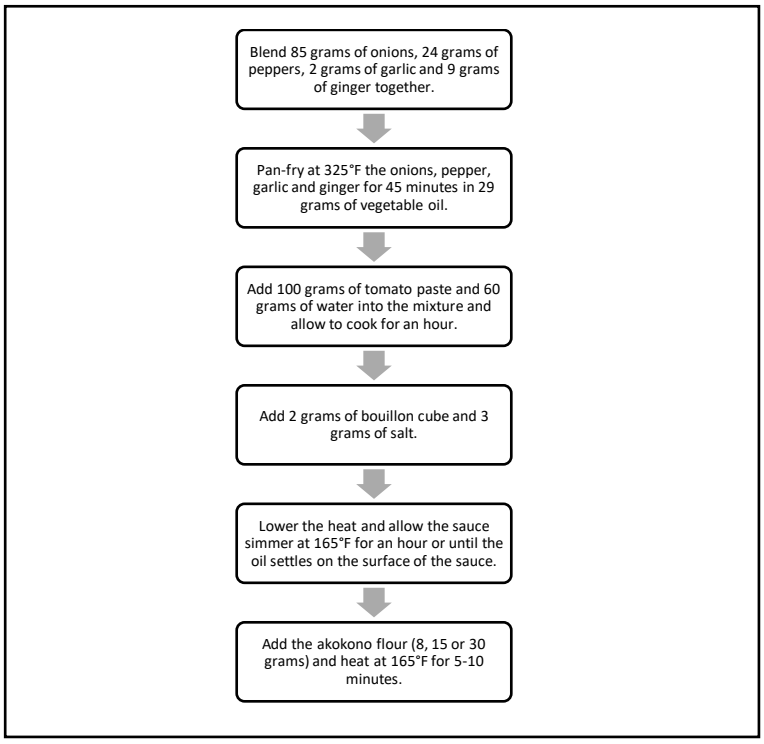

Figure 5.1 Preparation process of palm weevil larvae-fortified Ghanaian tomato sauce

The palm weevil larvae fortified tomato paste was prepared by mixing 100 grams of tomato paste with varying weights of *akokono* flour (8 grams, 15 grams and 30 grams) and heating it for about 5 to 10 minutes until the appropriate texture was reached. The processes involved in the production of the tomato sauce are presented in Figure 5.1.

5.2.3 Proximate analysis

The proximate analysis was carried out according to AOAC (Association of Official Analytical Chemists, 1995) and done in duplicates.

5.2.3.1 Determination of moisture content

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Moisture content of the tomato paste was determined according to the official methods of analysis (AOAC 927.05) (Association of Official Analytical Chemists, 1995). Samples were weighed and placed into dried and weighed moisture dishes before being dried in a vacuum oven at 70°C overnight, after which the dishes were placed in a desiccator to cool to room temperature and until a constant weight was obtained. The moisture content was expressed as a percentage of the average weight loss after drying the samples based on the following formula: $\frac{(W2-W3)}{W2-W1} * 100$ where W1 is the weight of the dish, W2 is the weight of the dish and the initial wet sample and W3 is the weight of the dish with the dried sample.

5.2.3.2 Determination of ash content

Ash is defined as the inorganic residue left after the food's organic residue has been burnt. Ash content was determined according to the official methods of analysis (AOAC 942.05) (Association of Official Analytical Chemists, 1995). *Akokono*-based tomato paste samples were weighed (one gram each) and transferred into dry and weighed crucibles. Samples were incinerated for 2 hours at 550°C in a muffle furnace. Samples were then allowed to cool to room temperature before being placed in a desiccator and weighed afterwards. The difference in weight was expressed as the ash percentage in the tomato paste: $\frac{(W2-W3)}{W1-W3} * 100$ where W1 is the weight of the crucible and raw sample, W2 is the weight of the crucible and dried sample and W3 is the weight of the crucible.

5.2.3.3 Determination of crude protein

The Dumas method (Association of Official Analytical Chemists, 1995) was used to determine the crude protein content of the *akokono* tomato paste samples. Samples were freeze-dried and then weighed (8 milligrams to 12 milligrams) into metal caps (which had been blanked

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beforehand). The amount of nitrogen was then quantified using a universal detector, NC Soil Analyzer, Flash 1112 Series EA (Thermo Finnigan). The crude protein content of samples is calculating by multiplying the percent Nitrogen with 6.25.

5.2.3.4 Determination of crude fat

The Soxhlet extraction method (Association of Official Analytical Chemists, 1995) was used for crude fat determination. Extraction cups were weighed before adding 50 milliliters of petroleum ether (solvent). Dried samples from the moisture determination were weighed (two to three grams each) and transferred into extraction thimbles. The thimble and the sample were then placed in a Soxhlet extractor (SER 148, Solvent Extraction VELP Scientifica) for about an hour and a half. Once the extraction was completed, the extraction cups were weighed, and the crude fat content was calculated according to the following formula:

$$\frac{Weight\ of\ extraction\ cup\ with\ fat - Weight\ of\ extraction\ cup}{Weight\ of\ sample} * 100$$

5.2.3.5 Determination of carbohydrates

Carbohydrates were determined according to the following formula:

$$100 - (\%\ crude\ fat + \%\ ash + \%\ crude\ protein) = \text{carbohydrate content}$$

5.2.3.6 Determination of dietary fiber

Dietary fiber was determined through a combination of enzymatic and gravimetric methods. Dietary fiber content was determined using the total dietary fiber assay kit (Sigma-Aldrich Co., USA) based on the AOAC 985.26 method. Defatted samples were weighed into beakers (0.5 grams) and gelatinized using α-amylase. Then, they were enzymatically digested with protease and amyloglucosidase to remove the protein and starch present in the sample. Ethanol was then

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added to precipitate the soluble dietary fiber. The residue was then filtered and washed with ethanol and acetone. After drying in a vacuum oven at 70 degrees Celsius, the residue was weighed. Half of the samples were analyzed for protein and the others were ashed. Total dietary fiber is the weight of the residue minus the weight of the protein and ash.

5.2.3.7 Determination of wet basis

Macronutrient and mineral contents were then expressed on wet basis according to the following formula:

$$X\ content\ \left(\frac{g}{100} g\ wet\ \boldsymbol{matter}\right) = \frac{100 - \%\ moisture\ content}{100} * X\ content\ (dry\ basis)$$

5.2.4 Mineral analysis

Mineral analysis was carried out in order to determine the content of iron and zinc using Inductively Coupled Plasma- Mass Spectrometry (ICP-MS) (Jajda et al., 2015). Samples of 0.5 grams each were weighed into 50-milliliters pre-cleaned Falcon tubes to which were added 6 milliliters of trace-metal grade nitric acid. The samples were heated in a water bath at 90 degrees Celsius for 2 hours then allowed to cool at room temperature. Hydrogen peroxide (3 milliliters) was added to these samples which were then heated in a water bath at 90 degrees Celsius for an additional hour until particulates were not visible. Solutions were diluted to 2% nitric acid and analyzed using ICP-MS. All proximate and mineral analyses were performed in duplicates using the same samples.

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5.2.5 Sensory evaluation of tomato paste and tomato sauce (hedonic tasting)

A consumer acceptability study was conducted among 88 participants (panelists) from five selected communities in Kumasi for all six tomato paste and sauce formulations. Each panelist evaluated a sample set of four random samples which were each assigned a 3-digit blinding code. Kilcast's recommendations for sample presentation were respected (Kilcast, 2010). White rice accompanied tomato sauce samples and saltine crackers were used as palate cleansers. Panelists were asked to rate the samples' following parameters: color, taste, texture and consistency, mouthfeel, and overall liking using a 5-point Likert scale. Panelists were also questioned about their overall acceptance of the products and their willingness to purchase them. They were then briefed on the nutritional benefits of palm weevil larvae after which they were asked to answer the previous questions again. All participants were informed about the allergenic potential of insects and the ones with a known shellfish allergy were excluded. Participants were informed that their participation was voluntary and were asked to sign a consent form. Prior to data collection, institutional review board approval was received from McGill University's Research Ethics Board (file # 20-01-032) and Kwame Nkrumah University of Science and Technology (KNUST)'s Committee on Human Research, Publication and Ethics.

5.2.6 Statistical analyses

Sensory evaluation data were analyzed using frequencies and proportions for categorical variables. McNemar's test was used to evaluate whether the proportions of customers accepting the products and willing to purchase them were significantly different before and after having been informed about the benefits of *akokono*. Analysis of variance (ANOVA) was performed to see if there was a significant difference in the overall liking of all samples at $p<0.05$. Multivariate analysis of variance (MANOVA) was then performed to determine if the samples

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were significantly different considering all the sensory attributes simultaneously at $p<0.05$. Binary logistic regression analyses were finally performed to identify the sensory attributes that were critical to the overall acceptance of the samples and respondents' purchase intent. ANOVA and the Tukey's honest significant difference test ($p < 0.05$) were used to detect significant differences among the nutrient contents of the different formulations.

5.3 Results

5.3.1 Determination of nutrient composition

The nutrient composition of the tomato paste enriched with *akokono* is presented in Table 5.1 (dry basis), Table 5.2 (wet basis) and Table 5.3 (per 200 grams of tomato paste). Tomato paste samples' total solids content ranged from 27.3% to 58.4%. Total solids increased with increasing *akokono* flour concentration. Results from the wet-basis analysis showed that the tomato paste samples' protein content ranged from 4.59 to 13.6 grams per 100 grams of tomato paste (wet basis). An increase in the protein content of tomato paste was observed with increasing *akokono* concentration. The protein content of the 30:100 *akokono*-fortified tomato paste sample was significantly higher than that of unfortified tomato paste. As for tomato paste's ash content, it increased significantly with an increasing concentration of *akokono* flour, going from 1.88 to 3.09 grams per 100 grams of tomato paste (wet basis). Tomato paste's fat content increased significantly with the addition of *akokono* going from 0.09 to 16.5 grams per 100 grams of tomato paste (wet basis). No specific trends were detected for fortified tomato paste's fiber and carbohydrate contents which varied between 1.13 to 2.45 grams and 18.3 to 25.2 grams, respectively, per 100 grams of tomato paste (wet basis). Moreover, the addition of *akokono* significantly increased tomato paste's iron and zinc contents (wet basis). Tomato paste's iron content increased from 1.74 to 3.83 milligrams per 100 grams of tomato paste (wet

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basis) and its zinc content increased from 0.16 to 1.99 milligrams per 100 grams of tomato paste (wet basis) with increasing concentrations of *akokono* flour. As for *akokono* flour, it had a low moisture content (5.92%), high protein (23.9 grams per 100 grams wet basis) and fat (54.1 grams per 100 grams wet basis) contents, moderate carbohydrate (11.8 grams per 100 grams wet basis) and fiber (5.36 grams per 100 grams wet basis) contents, and good iron (3.74 milligrams per 100 grams wet basis) and zinc contents (12.1 milligrams per 100 grams wet basis).

The estimated amount of nutrients that would be consumed on a daily basis assuming a consumption of 200 grams of tomato paste per day were presented in Table 5.3. Our findings showed that consuming 200 grams of the 30:100 *akokono*-fortified tomato paste would provide twice as much iron (7.66 milligrams), almost three times more protein (27.2 grams), and twelve times more zinc (3.98 milligrams) than consuming the same amount of unfortified tomato paste.

A one-way ANOVA and Tukey's honest significant differences test were performed to see whether the addition of palm weevil larvae to tomato paste had a significant impact on tomato paste's nutrient composition. Results from the ANOVA test revealed that samples had significantly different ash, moisture, fat, carbohydrate, fiber, iron, and zinc contents. Results from the Tukey's honest significant differences test comparing the significant difference of samples' means for each nutrient are presented in Tables 5.1, 5.2 and 5.3.

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Table 5.1 Nutrient composition of tomato paste samples with varying palm weevil larvae flour concentrations (dry basis)

Samples Ratio PWL:TP	Moisture content (%)	Ash content (% dry weight)	Protein content (% dry weight)	Fat content (% dry weight)	Carbohydrate content (% dry weight)	Fiber content (% dry weight)	Iron content (mg/100 g dry matter)	Zinc content (mg/100 g dry matter)
0:100	72.7 ± 0.07^{a}	6.87 ± 0.10^{a}	16.8 ± 0.14^{a}	0.33 ± 0.21^{a}	76.0 ± 0.71^{a}	4.17 ± 0.20^{a}	6.36 ± 0.09^{a}	0.61 ± 0.28^{a}
8:100	64.8 ± 0.49^{b}	6.61 ± 0.05^{a}	18.3 ± 0.05^{b}	19.0 ± 0.35^{b}	56.1 ± 0.77^{b}	5.20 ± 0.57^{b}	5.66 ± 0.47^{b}	2.27 ± 0.19^{a}
15:100	62.8 ± 0.49^{c}	6.34 ± 0.39^{a}	22.8 ± 0.21^{c}	21.7 ± 0.14^{c}	49.1 ± 0.19^{c}	6.60 ± 0.19^{b}	6.70 ± 0.14^{a}	3.00 ± 0.35^{b}
30:100	41.6 ± 0.21^{d}	5.29 ± 0.21^{b}	23.3 ± 0.42^{c}	28.2 ± 0.18^{d}	43.2 ± 0.15^{d}	3.20 ± 0.03^{c}	6.56 ± 0.11^{a}	3.41 ± 0.06^{b}
100:0	5.92 ± 0.06^{e}	4.49 ± 0.07^{b}	25.5 ± 0.28^{d}	57.5 ± 0.35^{e}	12.5 ± 0.37^{e}	5.70 ± 0.007^{b}	3.98 ± 0.18^{c}	12.9 ± 0.63^{c}

PWL: Palm weevil larvae flour

TP: Tomato paste

All values are expressed as mean ± SD. Sample means with different superscript letters in the same column are significantly different ($p<0.05$)

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Table 5.2 Nutrient composition of tomato paste samples with varying palm weevil larvae flour concentrations (wet basis)

Samples Ratio PWL:TP	Moisture content (%)	Ash content (g/100g wet basis)	Protein content (g/100g wet basis)	Fat content (g/100g wet basis)	Carbohydrate content (g/100g wet basis)	Fiber content (g/100g wet basis)	Iron content (mg/100g wet basis)	Zinc content (g/100g wet basis)
0:100	72.7±0.07^{a}	1.88±0.10^{a}	4.59±0.14^{a}	0.09±0.21^{a}	20.7±0.71^{a}	1.13±0.20^{a}	1.74±0.09^{a}	0.16±0.28^{a}
8:100	64.8±0.49^{b}	2.33±0.05^{b}	6.44±0.05^{ab}	6.68±0.35^{b}	19.7±0.77^{ab}	1.83±0.57^{b}	1.99±0.47^{b}	0.80±0.19^{b}
15:100	62.8±0.49^{c}	2.36±0.39^{c}	8.48±0.2^{ab}	8.07±0.14^{c}	18.3±0.19^{b}	2.45±0.19^{c}	2.49±0.14^{c}	1.11±0.35^{c}
30:100	41.6±0.21^{d}	3.09±0.21^{d}	13.6±0.42^{b}	16.5±0.18^{d}	25.2±0.15^{c}	1.87±0.03^{b}	3.83±0.11^{d}	1.99±0.06^{d}
100:0	5.92±0.06^{e}	4.22±0.07^{e}	23.9±0.28^{c}	54.1±0.35^{e}	11.8±0.37^{d}	5.36±0.007^{d}	3.74±0.18^{d}	12.1±0.63^{e}

PWL: Palm weevil larvae flour

TP: Tomato paste

All values are expressed as mean ± SD. Sample means with different superscript letters in the same column are significantly different ($p<0.05$)

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Table 5.3 Nutrient composition of tomato paste samples with varying palm weevil larvae flour concentrations (as consumed basis)

Samples Ratio PWL:TP	Moisture content (%)	Ash content (g/200 g tomato paste)	Protein content (g/200 g tomato paste)	Fat content (g/200 g tomato paste)	Carbohydrate content (g/200 g tomato paste)	Fiber content (g/200 g tomato paste)	Iron content (g/200 g tomato paste)	Zinc content (g/200 g tomato paste)
0:100	72.7 ± 0.07^{a}	3.75 ± 0.10^{a}	9.17 ± 0.14^{a}	0.18 ± 0.21^{a}	41.5 ± 0.71^{a}	2.28 ± 0.20^{a}	3.47 ± 0.09^{a}	0.33 ± 0.28^{a}
8:100	64.8 ± 0.49^{b}	4.65 ± 0.05^{b}	12.8 ± 0.05^{ab}	13.4 ± 0.35^{b}	39.5 ± 0.77^{ab}	3.66 ± 0.57^{b}	3.99 ± 0.47^{b}	1.60 ± 0.19^{b}
15:100	62.8 ± 0.49^{c}	4.72 ± 0.39^{c}	16.9 ± 0.2^{ab}	16.1 ± 0.14^{c}	36.6 ± 0.19^{b}	4.91 ± 0.19^{c}	4.99 ± 0.14^{c}	2.23 ± 0.35^{c}
30:100	41.6 ± 0.21^{d}	6.18 ± 0.21^{d}	27.2 ± 0.42^{b}	32.9 ± 0.18^{d}	50.5 ± 0.15^{c}	3.74 ± 0.03^{b}	7.66 ± 0.11^{d}	3.98 ± 0.06^{d}
100:0	5.92 ± 0.06^{e}	8.45 ± 0.07^{e}	47.9 ± 0.28^{c}	108 ± 0.35^{e}	23.5 ± 0.37^{d}	10.7 ± 0.007^{d}	7.49 ± 0.18^{d}	24.3 ± 0.63^{e}

PWL: Palm weevil larvae flour

TP: Tomato paste

All values are expressed as mean ± SD. Sample means with different superscript letters in the same column are significantly different ($p<0.05$)

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5.3.2 Sensory evaluation

Characteristics of participants and purchasing frequency

Most panelists were women (77.5%) and over a third of them were aged between 25 to 34 years old (33%). Only a few participants had a university degree (19.3%), while almost half had completed secondary education (46.8%). Over 90% of participants were low-income earners with 40% earning below 500 GHC per month (equivalent to 47 USD per month). When asked about their awareness of iron and its importance in their diets, only half of the participants reported being well-informed on iron and recognized its significance for their health and well-being. Cross-tabulations and chi-square tests were conducted between participants' socio-demographic characteristics (age, gender, income level, educational attainment) and their willingness to purchase *akokono*-based tomato paste. No significant association was found.

Almost half of the participants (45%) reported consuming *akokono* for the first time during this sensory evaluation, while 31.6% indicated being occasional consumers (less than once a month). Consuming *akokono*, however, was more popular than purchasing it as 31% participants engaged in the former while 5% engaged in the latter, as seen in Figure 5.2. This implies that *akokono* is either being offered as a delicacy or is self-harvested.

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Table 5.4 Socio-demographic characteristics of participants and iron knowledge

	Proportion of participants (%)
Gender	
Women	81.8
Men	18.2
Age group (years old)	
18-24	24.3
25-34	35.6
35-49	17.0
50+	23.1
Income level (Ghanaian Cedis/month)	
Below 500	42.6
500-1500	53.8
1501-2000	1.20
2001-5000	2.40
Educational attainment	
No degree	14.6
Primary education	15.8
Secondary education	48.6
University degree	21.0

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Knowledge of iron	
Yes	51.4
No	48.6
Importance of iron	
Very important	47.7
Slightly important	2.40
I don't know	49.8

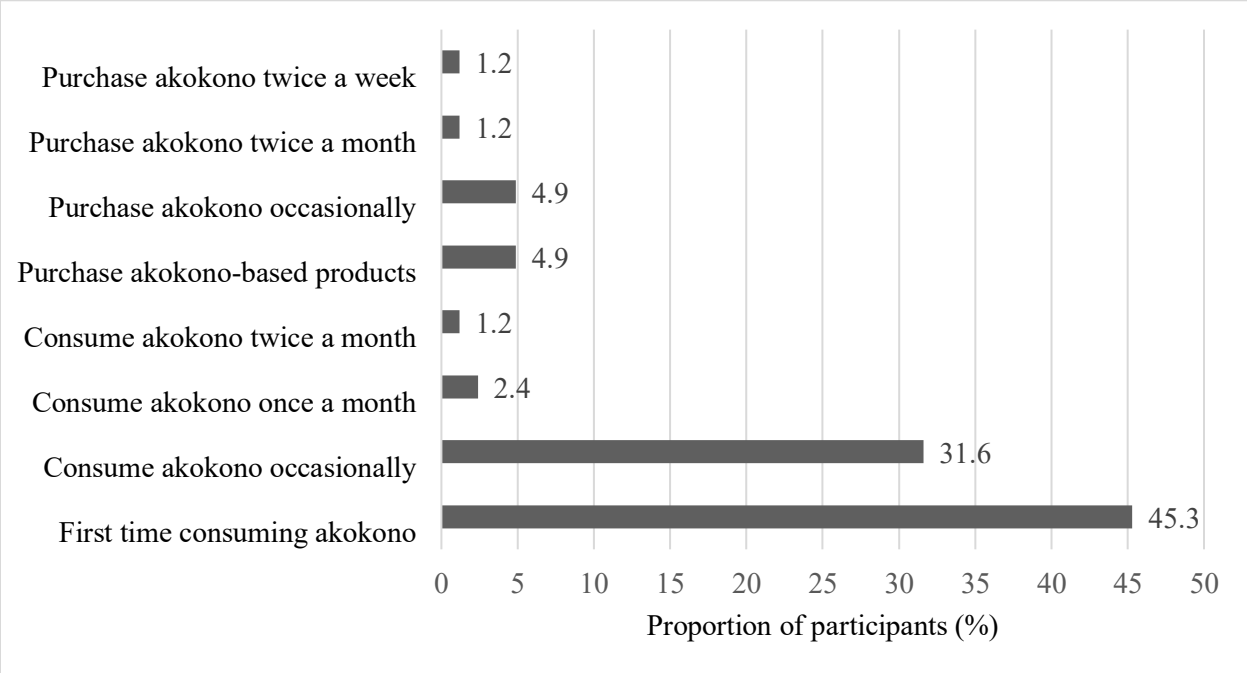

Figure 5.32 Akokono consumption and purchasing habits of respondents

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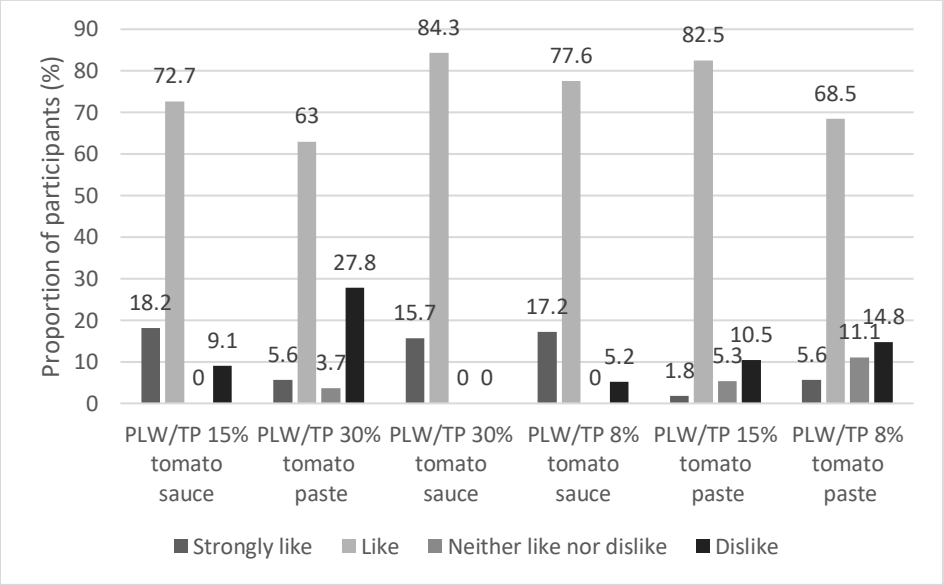
Likert-scale scores for overall liking and sensory attributes



Like/ Strongly like to dislike ratio:

PLW/TP, 15% tomato sauce: **10**

PLW/TP, 30%, tomato paste: **2.5**

PLW/TP, 30%, tomato sauce: **NA**

PLW/TP, 8%, tomato sauce: **18.2**

PLW/TP, 15% tomato paste: **8.0**

PLW/TP, 8%, tomato paste: **5.0**

Figure 5.3 Overall liking of tomato paste and sauce samples

The median Likert scale rating for all samples was 2, or "Like", indicating that participants generally liked all samples. When looking at Figure 5.3, samples [PLW/TP, 30%, tomato sauce] and [PLW/TP, 8%, tomato sauce], and [PLW/TP, 15% tomato sauce] were the most preferred by over 90% of the participants (Median 2; IQR 1, 0, 0 respectively) and had the highest like-to-dislike ratio. On the contrary, samples [PLW/TP, 30%, tomato paste] and [PLW/TP, 8%, tomato paste] were the most disliked with a higher variation in responses for the latter (IQR 1, 2 respectively). Results from the ANOVA test indicate that the difference in overall liking between all six samples is significant ($F=6.077$, $p<0.05$).

When looking at the sensory attributes evaluated for tomato paste and tomato sauce samples, as seen on Figure 5.4, we noticed that the colors of samples [PLW/TP, 30%, tomato sauce] and [PLW/TP, 15%, tomato paste] were the most liked, that the tastes of samples [PLW/TP, 15%, tomato sauce] and [PLW/TP, 15%, tomato paste], that the textures/ consistencies of samples

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[PLW/TP, 15%, tomato sauce] and [PLW/TP, 15%, tomato paste] were the most liked, and that the mouthfeels of samples [PLW/TP, 15%, tomato sauce] and [PLW/TP, 15%, tomato paste] were the most liked. There was a significant difference in the color ($F=4.562$, $p<0.05$), taste ($F=5.193$, $p<0.05$), and texture/ consistency ($F=2.762$, $p<0.05$) ratings of all samples.

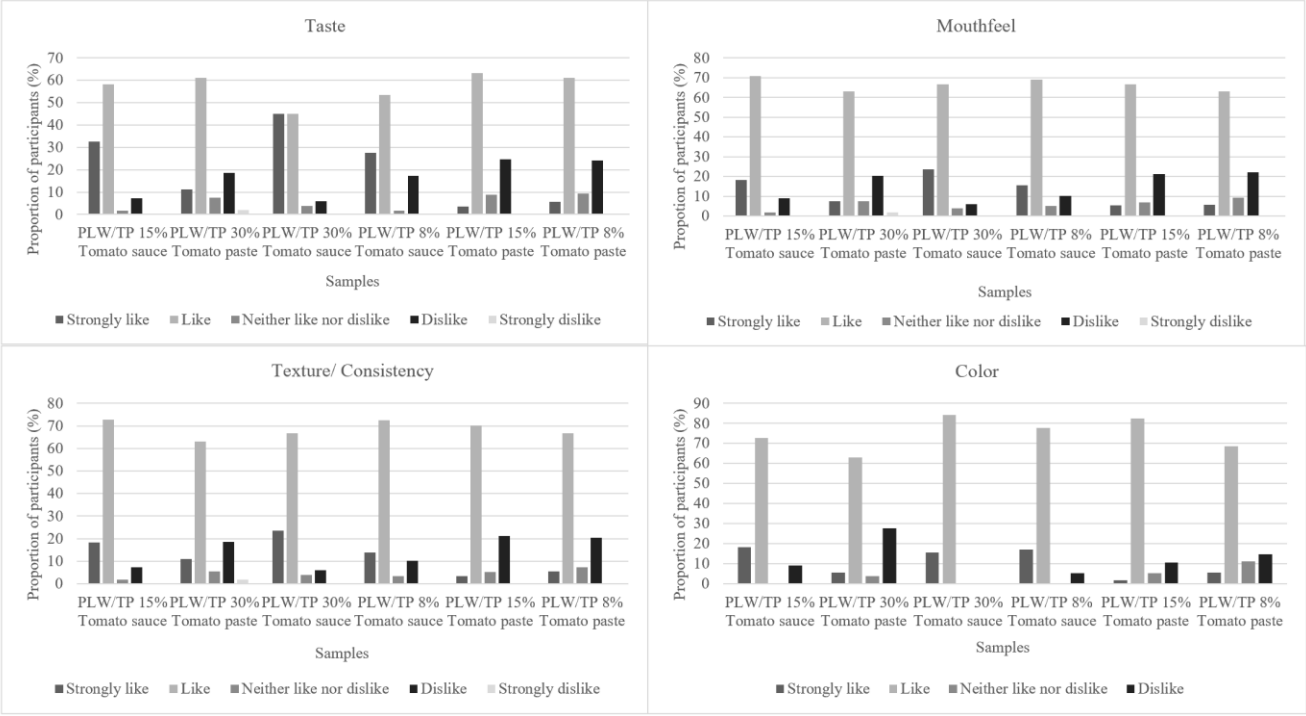

Figure 5.4 Sensory attribute ratings for tomato paste and tomato sauce samples

Statistical interpretation of tomato paste fortified with *akokono* formulations

For the multivariate analysis of variance (MANOVA), Wilks lambda's F-value greater than 1 and p-value less than 0.05 indicate that all formulations were perceived by the panelists as different (as seen in Table 5.5). In addition, the total-sample standardized canonical coefficient indicates the attribute that is more responsible for the differences. Our results from canonical 1 (Table 5.5) indicate that color and taste are the most responsible for the differences. Logistic regression was then performed with "overall acceptance" and "willingness to purchase" as the

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dependent variables and the sensory attributes as the independent variables. According to the results of logistic regression analysis, color and overall liking were found to be the most significant ($\alpha = 0.05$) and determinant for the overall acceptance of *akokono*-fortified tomato paste fortified and consumers' willingness to purchase it.

Table 5.5 Sensory analyses: sensory attributes critical to acceptance and purchase intent of tomato paste with varying concentrations of *akokono* flour

MANOVA					
Statistic	Value	*F* value	Num DF	Den DF	Pr>*F* value
Wilks' lambda	0.794	3.04	25	1186.5	<.0001
Pillai's trace	0.216	2.92	25	1615	<.0001
Hotelling-Lawley trace	0.246	3.13	25	773.66	<.0001
Roy's greatest root	0.178	11.53	5	323	<.0001

Total-sample standardized canonical coefficients		
Variable	**Canonical 1**	**Canonical 2**
Color	0.625	0.672
Taste	0.964	-1.58
Texture/ Consistency	-0.482	-0.996
Mouthfeel	-0.132	0.994
Overall Liking	0.223	1.015

Logistic regression analysis for acceptance*				
Variable	**Estimate**	**χ^2**	**Pr> χ^2**	**Odd's ratio**
Color	-0.901	7.22	0.0072	0.406
Taste	-0.367	0.465	0.499	0.693
Texture/ Consistency	-0.00688	0.0002	0.989	0.993
Mouthfeel	-0.0960	0.0243	0.876	0.908
Overall Liking	-2.33	14.06	0.0002	0.097

Logistic regression analysis for willingness to purchase*

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Variable	Estimate	χ^2	Pr> χ^2	Odd's ratio
Color	-0.533	3.99	0.0458	0.587
Taste	-0.549	1.72	0.189	0.578
Texture/ Consistency	-0.135	0.089	0.766	0.873
Mouthfeel	-0.296	0.348	0.555	0.744
Overall Liking	-1.246	7.68	0.0056	0.288

***Significance, α = 0.05

Influence of knowledge on acceptance and willingness to purchase

As seen in Figure 5.5, according to McNemar's test, there was a significant increase in respondents' willingness to purchase and accept all samples for consumption after they were informed about the potential nutritional benefits of consuming *akokono.* However, these differences were only significant overall, but not when looking at each sample separately.

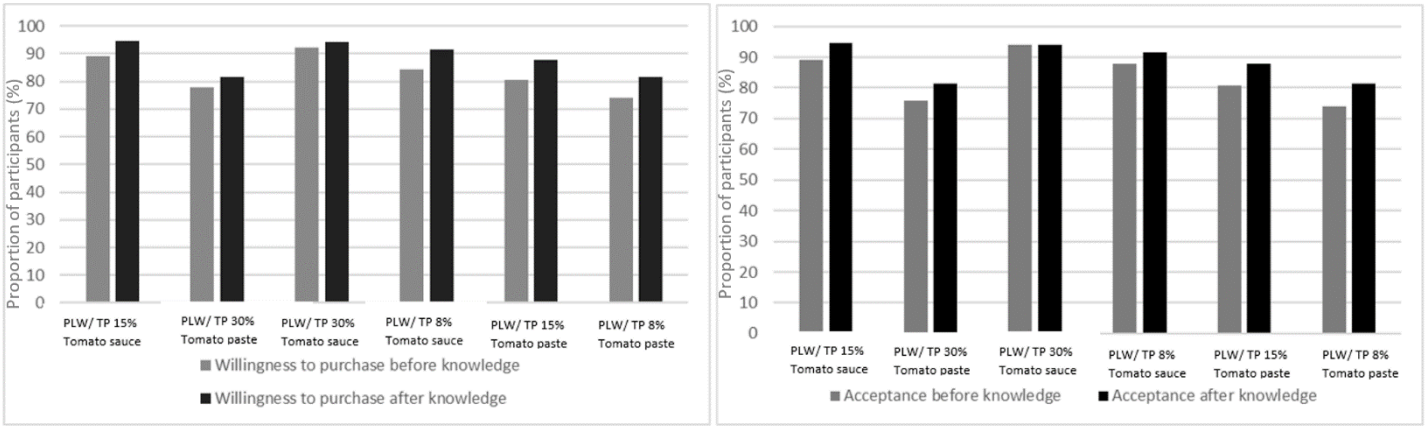

Figure 5.5: Acceptance and willingness to purchase *akokono*-products before and after knowledge on benefits
p<0.05 for both using McNemar's test: there is a significant difference as a whole.
But when look at each blinding code, no significant difference

5.4 Discussion

This study presents the nutritional composition of tomato paste samples fortified with palm weevil larvae (*akokono*), an edible insect consumed in Ghana, and evaluates Ghanaian community members' acceptance and willingness to purchase the prepared product formulations.

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5.4.1 Nutrient composition of *akokono*-based tomato paste

The samples' macronutrient composition will be analyzed based on the dry-basis values obtained (Table 5.1) in order to compare them to those found in the literature. The addition of *akokono* increased tomato paste's total solids content thus increasing its nutrient content. The addition of *akokono* significantly increased tomato paste's fat content, suggesting that it will contain higher amounts of fat-soluble vitamins, essential fatty-acids and energy. The *akokono* flour's crude fat content (57.5%±0.35) was in agreement with values reported in the literature, which varied between 52.4% and 66.6% (Chinarak, Chaijan, & Panpipat, 2020; Edijala, Egbogbo, & Anigboro, 2009; Ekpo & A.O, 2005; Elemo, Elemo, Makinde, & Erukainure, 2011; Omotoso & Adedire, 2007; Parker et al., 2017; Womeni et al., 2012). *Akokono*'s high fat content is seen to contribute to its acceptable taste and flavor profile when roasted; however, it may increase its susceptibility to storage deterioration via lipid oxidation (Ekpo & A.O, 2005).

The addition of *akokono* increased tomato paste's protein content and complemented efficiently its amino acids composition. Our proximate analyses showed that *akokono* and tomato paste's protein contents (25.5% and 16.8% dry weight basis, respectively) corroborated the values reported in the literature stating that *akokono*'s protein content varied between 19.50% and 69.78% (dry weight basis) (Rumpold & Schlüter, 2013), and tomato paste's protein content ranged between 10.50% and 25.03% (Ali et al., 2021). According to several studies, palm weevil larva contains almost all of the essential amino acids in adequate quantities except for tryptophan (Chinarak et al., 2020; Ekpo & A.O, 2005; Elemo et al., 2011; Womeni et al., 2012). Of particular interest are its high levels of leucine, lysine, and threonine, which are limiting amino acids in grains and cereals. Tomato paste contains on average 2.80 milligrams of leucine, 2.45 milligrams of lysine, and 1.37 milligrams of threonine per 100 grams of protein (Ali et al., 2021),

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which is almost fifteen times less than what is found in *akokono*. *Akokono* are comprised of 47 milligrams to 59 milligrams of leucine, 42 milligrams to 64 milligrams of lysine, and 29 milligrams to 31 milligrams of threonine per 100 grams of protein (Rumpold & Schlüter, 2013).

The dry weight basis fiber content remained relatively stable with the addition of palm weevil larvae. This was expected as both tomato paste and palm weevil larvae have similar fiber contents. Canned tomato paste's fiber content has been reported in the literature as varying between 4.97% and 6.61% (dry weight basis) (Abdullahi, Abdullahi, Abdu, & Ibrahim, 2016) which aligns with the value we found (4.17%±0.20), while *akokono*'s fiber content has been reported as varying between 2.58% and 22.9% (dry weight basis) (Rumpold & Schlüter, 2013) which compares to our *akokono*'s fiber results of 5.70%±0.007 (dry weight).

The carbohydrate composition (dry basis) of the fortified tomato paste decreased with increasing concentrations of *akokono* flour. This was expected as *akokono's* carbohydrate content is lower than that of tomato paste. Our *akokono's* carbohydrate content (dry weight basis) (12.51%±0.37) corroborated the ranges found in the literature which varied from 4.21% to 48.50% (dry weight basis) (Ekpo & A.O, 2005; Rumpold & Schlüter, 2013; Womeni et al., 2012).

As for the iron and zinc contents, their wet-basis values were analyzed as they were more indicative of the amount that would be theoretical consumed. The addition of *akokono* increased significantly tomato paste's zinc and iron contents (wet basis) with increasing *akokono* concentrations. Moreover, a daily consumption of 200 grams of 30:100 *akokono*-fortified tomato paste would theoretically provide women twice as much iron (7.66 milligrams of iron) than the unfortified tomato paste (3.47 milligrams of iron) would. This finding is important as it suggests

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that fortifying tomato paste with 30% (or more) *akokono* could significantly improve women's daily consumption of iron.

5.4.2 Sensory evaluation of samples fortified with *akokono* flour and factors influencing consumer acceptability and willingness to purchase

Our results show no typical consumer profile for *akokono* as participants from different genders, age groups, income levels, educational attainments were all interested in *akokono* and expressed willingness to purchase *akokono*-based products.

The logistic regression analyses showed that the overall acceptance of the tomato paste samples and consumers' willingness to purchase them were significantly dependent on the samples' color and consumers' overall liking of the products ($p < 0.05$). Our findings corroborate with Smarzynski (2019) and their colleagues who also identified color as a determining factor in consumers' acceptance of a pork pâté fortified with cricket powder (Smarzyński et al., 2019). Visual cues like color are essential determinants of a food product's acceptance since they are indicators of a product's freshness (Arce-Lopera, Masuda, Kimura, Wada, & Okajima, 2015; Grunert, 1997). As a result, if a product's color is unacceptable, flavor and texture are unlikely to be properly judged. When Keneko and colleagues (2002) evaluated consumer acceptability of color in tomato-processed products, they determined that a peak color acceptance existed for all tomato-products, stating that those were undesirable if they were too red or too brown (Claybon & Barringer, 2002). For tomato sauce specifically, they found that consumers preferred it to be closer to the "red" end of the spectrum, indicating that consumers wanted a fresher product, rather than a more processed product, which would have been associated with a browner product (Claybon & Barringer, 2002). Taste and texture also motivated women's overall acceptance and willingness to purchase the *akokono*-based tomato paste and sauce, if sold on the market. The

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sensory evaluation was performed on women, majorly (over 80%), as they are responsible for food purchasing and preparation in the household. When asked to justify their liking and willingness to purchase, women mentioned they were motivated by the fact that the tomato paste's taste and color remained appealing despite adding *akokono.* Some specified they would only buy *akokono* if it were added to tomato paste, as they would know how to cook it and could seamlessly incorporate it into theirs and their children's diets. The use of palm weevil larvae in a known and commonly consumed food product such as tomato paste seemed to have increased familiarly with *akokono* and reduced the taboo associated with entomophagy. Familiarity, which is achieved by integrating insects in already well-known products and combining favorite dishes with insects, has been reported as essential in increasing acceptance of edible insects and decreasing neophobia among consumers (Wendin & Nyberg, 2021).

Most women preferred the tomato sauce sample with the highest concentration of *akokono* and indicated they would use it in stews to diversify their diets and make them more nutritious. Health and nutrition were factors that really motivated women's acceptance of *akokono*. A few other studies reported that nutrition was a major motive for insect consumption in developing countries (M. A. Ayieko & V. Oriaro, 2008; Manditsera et al., 2018; Obopile & Seeletso, 2013). Though respondents did not particularly know the insects' exact nutritional composition, they perceived them as being highly nutritional foods that are rich in health promoting components (Manditsera et al., 2018). When women were informed about *akokono*'s health benefits, including its potential to improve their iron status, their acceptance and willingness to purchase the products increased, though not significantly. We found, indeed, no significant association between participants' willingness to purchase *akokono*-based tomato paste and their iron knowledge. Out of the participants willing to purchase it, 50% reported being knowledgeable

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about iron. The link between nutrition knowledge and dietary habits, however, has been established in African countries as listed in Worsley's article (Worsley, 2002), including in Ghana (Rose Omari, 2017) and Ethiopia (Melesse & van den Berg, 2021). A study conducted in Ethiopia highlighted that nutrition knowledge was positively related to healthy attitudes, practices and diet quality (Melesse & van den Berg, 2021). In Ghana, people were generally aware of iron-deficiency anemia and its association with poor eating habits (Awuah et al., 2021; Rose Omari, 2017). Therefore, informing people of the potential benefits of *akokono* consumption on their iron status could serve in increasing their willingness to consume and purchase *akokono* and *akokono*-based products. Consumer knowledge could also be associated with awareness of the product's existence and availability (Owureku-Asare, Ambrose, Oduro, Tortoe, & Saalia, 2016), thus underlining the importance of informing Ghanaians about the existence of *akokono, akokono*-based products, and their access points.

Finally, some participants mentioned being motivated to accept *akokono* because it is produced locally which would decrease unemployment. A study conducted by Adams and colleagues concluded that the domestication of palm weevil larvae was financially viable at the micro-scale and could have practical implications for small-scale enterprise development in addressing problems of malnutrition and unemployment (Adams et al., 2021).

5.5 Conclusion

This study found that the addition of palm weevil larvae improved the nutritional composition of tomato paste and tomato sauce, specifically in terms of its protein, fat, zinc, and iron contents. In addition, women accepted the highest palm weevil larvae-fortified tomato paste sample owing mainly to its color and taste. For food-to-food fortification to be successful, it is

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important to recognize the importance of a food's sensory aspects and develop food products with familiar tastes and textures. Health and nutrition were additional common motives for women's acceptance and willingness to purchase palm weevil larvae and its derived products. We found among participants, however, a lack of knowledge and awareness about palm weevil larva's nutritional benefits, its cooking and preparation, its income generation potential, and its access points. This highlights the need for nutrition education to support the consumption of palm weevil larvae-tomato paste as a potential feasible strategy to curtail micronutrient deficiencies, such as iron-deficiency anemia, among women.

Based on the results of our study we consider that further research should: 1) assess the effect of heat on the nutritional composition of palm weevil larvae-fortified tomato paste, 2) examine the microbial quality of the palm weevil larvae-fortified tomato paste, and 3) evaluate the impact of a daily consumption of palm weevil larvae-fortified tomato paste on women's iron status.

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CHAPTER 6: DISCUSSION AND CONCLUSION

In this final chapter, the results from the preceding chapters are brought together to understand how to increase women's acceptance and access to palm weevil larvae in peri-urban communities in the Ashanti region in Ghana. We begin with a summary of the key novel findings across chapters 3, 4 and 5 and conclude with recommended future research directions.

6.1. Summary of key findings

Chapter 3 provided an insight into Ghanaian women's beliefs and acceptance of palm weevil larvae within their communities, as well as identified the factors influencing its consumption. Using mind-mapping and focus group discussions in selected peri-urban communities in the Ashanti region in Ghana, we explored the factors influencing women's propensity to consume palm weevil larvae, as well as their general knowledge of iron and iron-deficiency anemia. We were also interested in evaluating whether living in palm growing communities (PGC) altered women's perceptions and acceptance of palm weevil larvae as compared to those living in non-palm growing communities (NPGC).

Women from all communities were generally motivated to consume palm weevil larvae for its nutritional and health benefits. Women showed a surprisingly unanimous awareness of palm weevil larvae's adequate protein content and the latter's importance in one's diets. In addition, participants demonstrated a good understanding of iron, iron-rich foods, and their association with anemia. Our results differ from the findings of two studies conducted in rural Ghana which reported that over 85% of participants could not name iron-rich foods or foods that would aid with iron absorption (Adjei-Banuah et al., 2021; Wiafe et al., 2021). Our participants' iron-related knowledge seemed to come from health professionals. Participants expressed a

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strong trust in their health professionals' advice, care, and suggestions, though some of these recommendations were not entirely correct. The strong level of trust and satisfaction with the healthcare system was common among Ghanaian rural residents who have limited expectations of the health system and are easier to satisfy as compared with urban residents (Amoah, Nyamekye, & Owusu-Addo, 2021). We noticed how doctors' recommendations shaped women's desire to consume certain products, including palm weevil larvae. An important first step in improving dietary practice is, therefore, to educate both women and health professionals on palm weevil larvae's benefits and utilization. Children were also influential in women's food-related decision making for the household, thus highlighting the importance of including children in nutrition education strategies.

We found no significant differences in women's perceptions about palm weevil larvae based on their locations. Women unanimously expressed that disgust and scarcity were the two major barriers to the consumption of palm weevil larvae. This finding was surprising in palm-growing communities as one might think that residing close to palm trees would grant them access to the trees and therefore to the larva. Participants also mentioned not knowing how to prepare or utilize the larvae. These findings point to an increasing loss of cultural knowledge which according to Raneri et al. (2019), was caused by the perception that neglected and underutilized species like edible insects, are a "poor man's food", especially for young people (Raneri, 2019). This negative impression hinders these species' use, exacerbates cultural erosion and loss of knowledge about food preparation methods, and contributes to younger generations' detachment from ancestral foods (Raneri, 2019). Interventions, therefore, need to educate and equip future generations with appropriate information and tools to adequately farm palm weevil larvae and maximize its utilization. Moreover, women expressed mixed opinions about

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consuming processed palm weevil larvae. While some viewed processing as a means to increase the larvae's availability and preservation, others considered it detrimental to the larvae's nutritional value. Some women were not concerned about consuming processed palm weevil larvae as long as they were the ones doing it to have control over the processing conditions (particularly from a hygiene perspective).

Palm weevil larvae's scarcity was mentioned by most women in PGC and NPGC. Due to palm weevil larvae' seasonality, it is not always feasible to harvest it from felled palm trees. Even when it is possible, the task is arduous and requires trained labor force. Because harvesting is not accessible to all, palm weevil larvae's semi-domestication was introduced in Kumasi. This initiative, however, did not seem to increase the insect's accessibility. As a result, our second study consisted of evaluating the factors contributing to palm weevil larvae's marketability and access to residents of the Ashanti region.

Chapter 4 aimed to examine the facilitators and barriers to the sale and access to palm weevil larvae at each step of its value chain from two perspectives: the seller and the customer. Additionally, this study aimed to explore the socio-economic and demographic factors associated with customers' purchasing frequency of palm weevil larvae. In this study, marketability was used as a proxy for accessibility. One way of increasing food access and customer outreach is through sale. Improving a product's marketability can therefore increase its sale and accessibility and contribute to improved nutritional outcomes. Marketability and market access have, in fact, been associated with improved food security and dietary diversity (Usman & Callo-Concha, 2021).

This study included surveys with customers purchasing palm weevil larvae and in-depth interviews with known farmers and sellers of palm weevil larvae in the Ashanti region in Ghana.

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Most of the barriers identified by the seller could be resolved by increasing funding for research and development in the area of edible insect processing, innovative technologies, and nutrition education. Researching preservation and storage techniques to increase palm weevil larvae's shelf life can facilitate its distribution and decrease food losses and waste. Research on the safety of palm weevil larvae and nutrient losses after processing is also necessary to promote and maximize the insect's use. The issue of affordability was also highlighted by customers and sellers who both stated that palm weevil larvae was more of a delicacy/ snack than a staple food.

In addition to palm weevil larvae's unaffordability, additional factors constituting customers' external and internal food environments influence their purchasing habits. These factors pertain to customers' personal food environment and refer to the individual-level influences on their food choices including food accessibility, convenience and desirability (Turner et al., 2018). A study conducted by Hirvonen et al. (2019) corroborated these factors (Hirvonen, Bai, Headey, & Masters, 2020). Customers' access to markets selling palm weevil larvae is influenced by their physical distance to the markets, transit time and mode of transportation, which are all modifiable factors. Over 70% of participants spent over 15 minutes in public transportation to reach the markets. Less than 3% of participants walked to the markets as the latter were very distant from participants' residences. Increasing the number of markets selling palm weevil larvae would increase its accessibility for customers and subsequently increase its consumption.

Moreover, nutrition and food preparation knowledge are key to influencing customers' food purchases. Several participants noted being intimidated by palm weevil larvae due to being unaware of how to prepare it. With proper nutrition education, customers could acquire the missing skills and knowledge to incorporate palm weevil larvae in their households' diets.

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Furthermore, palm weevil larvae's desirability is influenced by its appeal which can be achieved by diversifying and developing new insect-based products.

Finally, gender and educational attainment were the only socio-economic and demographic variables that were significantly associated with customers frequent purchase of palm weevil larvae. Our results showed that men were more inclined to purchase palm weevil larvae due to women's time constraints with having to tend to their children and households. In addition, we could think that one of the reasons people with higher educational attainments were purchasing palm weevil larvae more frequently could be related a market's location. One of the major markets was located near Kwame Nkrumah University of Science and Technology which can explain attracting highly educated people such as university students and professors.

After having determined the key barriers to palm weevil larvae's access in the Ashanti region and having suggested strategies to overcome them, we decided to evaluate the potential feasibility of fortifying a staple food product with palm weevil larvae to increase women's acceptance of it.

Chapter 5 consisted in developing a palm weevil larvae-fortified tomato paste, conducting a sensory evaluation that explored the attributes contributing to consumers' acceptance and willingness to purchase the product, as well as examining whether knowledge about the importance of iron influenced consumers' willingness to purchase and consume the fortified tomato paste.

Tomato paste was the chosen food vehicle to be fortified with palm weevil larvae as tomatoes are omnipresent in the Ghanaian diet, are widely produced, and are available all year long (Ministry of Food and Agriculture (MoFA), 2020; Van Asselt et al., 2018). Tomatoes fit the eligibility criteria we had established for the food vehicle: they are a good source of nutrients

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(except of iron) and have low levels of antinutrients (Oyetayo & Ibitoye, 2012; Sainju et al., 2003). The addition of palm weevil larvae improved tomato paste's macronutrient profile, zinc, and iron content. Tomato and its derived products are one of the most consumed commodities in Ghana (Ministry of Food and Agriculture (MoFA), 2020). In fact, in a recent study surveying 384 Ghanaians living in the Accra Metropolis, 96% of respondents mentioned consuming tomato products at least three days a week, with 70% of them consuming these products every day (Owureku-Asare et al., 2016). The consumption of palm weevil larvae-fortified tomato paste could, therefore, have the potential to significantly improve the prevalence of iron-deficiency anemia among women and children.

Out of all the fortified tomato paste's sensory attributes, color and overall liking influenced consumers' willingness to pay for the product and to accept it for consumption. Overall liking was described to participants as "considering all the product's attributes at once, do you generally like the product?". Participants preferred the tomato paste with the highest concentration of palm weevil larvae (30% weight by weight). This finding was surprising since the addition of 30% palm weevil larvae did darken tomato paste's initial color. We had chosen not to add more than 30% weight by weight because of the changes in tomato paste's color and taste which were imparted by the addition of palm weevil larvae. Our results suggest that our fortification margin is larger than we had anticipated. We should therefore try incorporating a higher proportion of palm weevil larvae into tomato paste and test its acceptance.

Finally, brief nutrition education on palm weevil larvae's benefits was shown to influence consumers' willingness to purchase the fortified tomato paste, suggesting that a proper nutrition education intervention could facilitate the acceptance and incorporation of palm weevil larvae into popular Ghanaian products.

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Overall, this thesis allowed us to answer our research questions and meet the specific objectives we had set. Namely, our findings from Chapter 3 allowed us to gain a clear understanding of women's perceptions of consuming palm weevil larvae and the factors influencing it. We identified "access" and "disgust" as the key barriers to women's consumption of palm weevil larvae and addressed each of them in our subsequent Chapters 4 and 5. Through Chapter 4, we examined the factors influencing Ghanaians' access to palm weevil larvae in peri-urban communities in the Ashanti region, and through Chapter 5, we examined whether fortifying tomato paste with palm weevil larvae would facilitate accepting the insect for consumption and decrease the disgust associated with it. We found that adding palm weevil larvae to tomato paste was not only effective from an acceptability perspective, but also beneficial from a nutritional perspective. The addition of palm weevil larvae enhanced tomato paste's macronutrient (mainly protein and fat), iron, and zinc contents.

6.2 Strengths and Limitations

The following are some of the strengths of this study. We used formative research through mind mapping to gain an initial understanding of Ghanaian's perceptions, beliefs, and apprehensions with palm weevil larvae. This helped inform and refine the development of our focus group interview guide, in-depth marketability interview questionnaire, and marketability survey. This was the first study to evaluate the association between socio-economic factors and customers' purchasing frequency of palm weevil larvae. These findings can support the design of interventions that are better tailored at promoting entomophagy in Ghana. This was also the first study to evaluate Ghanaians' thoughts and acceptance of tomato paste fortified with palm weevil larvae. Finally, findings from this study allowed to identify strategies that could be implemented

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at every step of palm weevil larvae's value chain to increase its access, consumption, and acceptance among Ghanaians.

This thesis had also limitations. Data collection took place during the COVID-19 pandemic which limited the number of participants we had initially planned to work with. We believe that the data we collected, however, allowed us to thoroughly answer our research questions. In addition, a community that was initially interested in participating dropped out from the study during data collection due to having experienced "helicopter researcher" with another researcher working on palm weevil larvae and associated us with them. This loss was unfortunate as we could have benefited from this community's residents' knowledge. Moreover, the student researcher coded all the focus group and in-depth interview transcripts and no independent person coded alongside to ensure inter-coder reliability. The use MAXQDA 2020 programme (VERBI Software, Berlin) for coding, however, helped with consistency in coding as the work window made it possible to see all previously used codes which were very well defined. The eligible participants for our in-depth interviews were very limited as there was only one recognized seller of palm weevil larvae in Ghana. Our small sample size did not allow us to get different sellers' perspectives on the sale and marketability of palm weevil larvae in Ghana. That being said, our findings could serve as a foundation and guide future researchers in furthering the assessment of palm weevil larvae's marketability. Finally, sensory evaluations were conducted in the field instead of in a sensory room where environmental variables are controlled (including the lighting, humidity and outdoor temperature). This lack of control could have resulted in experimental error in the data.

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6.4 Future Directions and Conclusions

Findings from this research can inform the programs and policies that are currently implemented by Ghanaian governmental organizations such as Ghana Health Service (GHS), Ghana Standards Authority (GSA), and Ghana's Ministry of Food and Agriculture (MoFA) and address the implementation gaps. First, in Ghana, GSA and GHS are responsible for drafting standards and regulations on food product labelling, which are later regulated by the Food and Drug Administration organization (Abu et al., 2021). These organizations should start drafting standards on the proper and safe development and processing of edible insects-based food products. Adequate regulations could facilitate the uptake and acceptance of palm weevil larvae and its derived products among Ghanaians who feared its unhygienic handling and processing. Moreover, our findings support the addition of palm weevil larvae flour to complementary foods to increase their iron content. Most Ghanaian food processors use staple cereals and grains in the development of complementary food products like the Tom Brown porridge. These staple foods, however, contain high levels of antinutritional factors which negatively impact the absorption of non-heme iron. Adding palm weevil larvae (which contains heme-iron) to complementary foods could therefore overcome the negative effects of antinutritional factors and increase women and children's iron intake. Furthermore, this dissertation's findings could encourage the Ghanaian government to look into considering other food vehicles than wheat flour, such as tomato paste, for their national iron fortification strategy. This could be especially important since low consumption of iron-fortified wheat flour has been reported in Ghana (Abu et al., 2021; Nyumuah et al., 2012). Additional efforts should be made in providing nutrition education to women of reproductive age within communities about iron-deficiency anemia, iron-rich foods and ways to increase iron absorption. Ghana Health Service should collaborate with Legendary

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Foods Africa in educating women about the nutritional and environmental benefits of palm weevil larvae and about the different ways to consume it. Finally, MoFA should look into collaborating with Legendary Foods Africa to develop a programme which would: 1) train women on how to rear and domesticate palm weevil larvae, 2) provide women with equipment and funds to build a small farm, and 3) educate women about palm weevil larvae's income generating potential and financial literacy.

Several novel findings emerged from this research, providing important contributions to the literature. With that being said, this dissertation revealed a number of areas that would benefit from further research as follows:

- Due to resource and logistic constraints, this study focused on prioritizing women's perspectives as they are usually the ones responsible for food preparation within the household. Further research should, however, seek to capture men's perceptions to provide a more complete understanding. This would allow for gender comparisons on the beliefs and perceptions associated with palm weevil larvae consumption and would provide insight as to how to best engage men in palm weevil larvae's value chain.
- Since knowledge about the importance of iron and palm weevil larvae's benefits influenced women's acceptance to consume and purchase the insect, further studies should evaluate the effect of a nutrition education intervention on women's consumption level of palm weevil larvae and their overall dietary diversity.
- Our findings are largely drawn from the experiences of women living in the Ashanti region in Ghana. It would be valuable to evaluate women's acceptance of the developed product in other regions in Ghana.

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- Since the developed palm weevil larvae-fortified tomato paste was accepted by women and was significantly richer in iron and zinc than regular tomato paste, a randomized-controlled trial should be conducted to assess the impact of a daily consumption of the fortified tomato paste on women's iron status and the prevalence of iron-deficiency anemia.
- Further studies should investigate evaluating the microbial quality of palm weevil larvae-fortified tomato paste and examine the impact of canning it on reducing its microbial activity and extending its shelf-life. This step would be crucial before pursuing the development and commercialization of the fortified tomato paste.
- Finally, our findings support the importance of domesticating palm weevil larvae at community-level and of promoting the production of palm weevil larvae-based fortification foods, an approach that would be co-designed and led by Ghanaian women. Women would farm their larvae, incorporate it into their diets, and sell it at local markets to generate income, giving sustainability to this system. Further research should assess the financial feasibility of this approach and the resources required to kickstart it.

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APPENDICES

Appendix 1: Consent forms and data collection tools

a. Consent form: focus groups
b. Consent form: sensory analyses
c. Consent form: marketability survey
d. Participation information letter
e. Focus group discussion guide
f. Marketability survey questionnaire
g. Sensory evaluation questionnaire

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Consent Form: Focus Groups

Project Title: The use of palm weevil larvae in food fortification for women of reproductive age in the Ashanti region in Ghana

Purpose: We are from McGill University and are conducting a research study in Ghana in collaboration with Aspire Food Inc. You are invited to participate. The purpose of the study is to examine women's attitudes, beliefs, perceived benefits and acceptance of *akokono* for consumption and sale as well as their involvement in *akokono*'s farming and sale within their communities. Additionally, this study explores women's knowledge and beliefs regarding nutrition, their job and food preparation. We are doing this to understand how to better use *akokono* to benefit women nutritionally and financially.
The focus group discussion will be semi-structured discussions using open-ended questions. The focus groups will be conducted by X (name of moderator- TBD), X (note taker).

Procedures: If you participate in this study, you will be in a group of approximately 8 to 13 people. A moderator will be asking questions and facilitating the discussion while another research assistant will be taking a few notes to write down the ideas expressed within the group. If you volunteer to participate in this focus group, you will be asked some questions relating to your experience with *akokono,* work, nutrition and food preparation. These questions will help us to better understand the issues at hand. Your participation is completely voluntary. You may withdraw from this study at any time without penalty.

Benefits and Risks: Your participation may benefit you, your family and community by helping to improve your nutrition and the uses of *akokono*. No risk greater than those experienced in ordinary conversation are anticipated. Everyone will be asked to respect the privacy of the other group members. All participants will be asked not to disclose anything said within the context of the discussion, but it is important to understand that other people in the group with you may not keep all information private and confidential.

Confidentiality: The focus group discussions will be audio-recorded, if you agree; however, your name will not be recorded on the tape. Your name and identifying information will not be associated with any part of the written report of the research. Moreover, if you consent, your picture will be taken during the discussions. No photos will be used without your permission. Permitted photos will be presented by myself, the principal investigator, Loloah Chamoun, anonymously during the dissemination of results. Your names will not be linked to the photos, neither will your community's location. No other information regarding your age, number of children, income level, religious beliefs, type of employment or place of employment will be ascribed to the photos.
All of your identifying information (including the audio recorded tape) will be kept confidential. The only people with access to identifiable information will be myself, the principal investigator, Loloah Chamoun, and my supervisor, Dr. Hugo Melgar-Quiñonez from McGill University.

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Consent: Please sign below if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities. A copy of this consent form will be given to you and the researcher will keep a copy.

Yes:___No:___You consent to be photographed.
Yes:___No:___You consent to be audio-taped.
Yes:___No:___You consent for the photographs to be shown during the dissemination of results.

Participant's signature: _____

Printed name: _____

Date: _____

If you have any questions or concerns about this study, please contact the Principal Investigator, Loloah Chamoun at Loloah.chamoun@mail.mcgill.ca or the Supervisor, Dr. Hugo Melgar-Quinonez at hugo.melgar-quinonez@mcgill.ca
For concerns related to your rights and welfare as a research participant you may contact Lynda McNeil from the Research Ethics Board at McGill University at Lynda.mcneil@mcgill.ca or at (514-398-6831)

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Consent Form: Sensory Analyses

Project Title: The use of palm weevil larvae in food fortification for women of reproductive age in the Ashanti region in Ghana

Introduction: We invite you to participate in a taste panel to assess an *akokono*-fortified food product. This research is being conducted by myself, Loloah Chamoun, principal investigator and PhD student at McGill University. Your participation could lead to the development of a new food product that could serve nutritional benefits to you and your family. Your participation in this is study is voluntary and you may withdraw at any time without any penalty.

Purpose of the Study: The purpose of this study is to evaluate the flavour and overall acceptability of an *akokono*- fortified food product prepared by researchers at McGill University. Your participation could lead to the development of a new food product that could serve nutritional benefits to you and your family.

Study Design and Your Time Commitment: Participation in this study requires a time commitment of approximately 15 to 20 minutes. The sensory evaluation will consist of three simple taste tests where you will be asked to rate the samples according to your degree of likeness from "like extremely" to "dislike extremely". The sensory qualities which will be evaluated include: color, taste, sweetness, texture and overall liking.

Who can participate in the study? You may participate in the study if you are willing to eat *akokono*, are in good health and have no food allergies or sensitivities. You must be aged between 18 and 45 years old, be literate in English, and be free from health conditions that restrict food choice. You should refrain from eating, drinking, or smoking at least 20 minutes before sensory testing. Please do not use perfumes or other strongly scented products on the day of the sensory test.

Who will be conducting the research? The study will be conducted by myself, Esi Aduku, field supervisor, as a requirement for her PhD research project. Two research assistants will assist her in setting up and conducting the taste panels.

Safety: All sessions will be conducted using hygienic practices.

Possible Risks and Discomforts: You will be required to remain seated for approximately 30 min. If you are unable to do so you will be allowed to stand in the sensory area. If you have any food allergies (specifically a shellfish allergy, or an allergy to tropomyosin) or sensitivities or are under medication which restricts free food choice you must not participate in this study. If you experience one or more of the following symptoms after consuming the food products: tingling the your mouth, abdominal pain, nausea, diarrhea, vomiting, trouble breathing, skin reactions such as itching hives or eczema, swelling of the face, lips, tongue, throat, ears, fingers or hands and/ or dizziness, please stop eating the food products. If this occurs during the tasting session, inform the nurse who will be

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present during the tasting. You may have to be administered antihistamines by the nurse to alleviate certain symptoms. However, if you experience a severe allergic reaction, the nurse (trained in epinephrine injection) will most likely give you an injection of epinephrine. After being done with the tasting, you will be asked to stay at the sensory evaluation room for 30 minutes in order to ensure no allergic reaction will occur. However, if you experience the aforementioned symptoms after you leave the sensory evaluation room, please go to the KNUST hospital (located at KNUST, Kumasi, Box KNUST) immediately. Your participation in this study is completely voluntary. You are free to withdraw from the study at any time for any reason without any penalty.

Benefits to Participation: Your participation in this study will provide information to our researchers at McGill University on the flavour and acceptability of our *akokono*-fortified food product. Your participation could lead to the development of a new food product that could serve nutritional benefits to you and your family.

Confidentiality and Anonymity: We will make every possible effect to respect your confidentiality. Names of individuals participating in the study will be known only to the Sensory Panel Organizer (Loloah Chamoun), Sensory Panel Supervisor (Dr. Hugo Melgar Quinonez) and research assistants and will be destroyed upon completion of the sensory test. Anonymous score sheets will be used during sensory testing, and your name will not be linked in any way to the data collected. We remind you that the sensory testing sessions will be conducted in a public setting, and we ask you to respect the privacy of other taste panel participants.

Consent: Please sign below if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities. A copy of this consent form will be given to you and the researcher will keep a copy.

Participant's signature: _____

Printed name: _____

Date: _____

If you have any questions or concerns about this study, please contact the Principal Investigator, Loloah Chamoun at Loloah.chamoun@mail.mcgill.ca or the Supervisor, Dr. Hugo Melgar-Quinonez at hugo.melgar-quinonez@mcgill.ca
For concerns related to your rights and welfare as a research participant you may contact Lynda McNeil from the Research Ethics Board at McGill University at Lynda.mcneil@mcgill.ca or at (514-398-6831).

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Consent Form: Marketability Survey

Project Title: The use of palm weevil larvae as a livelihood strategy and a food fortification approach for women of reproductive age in Ghana.

Introduction: You are invited to participate in a survey related to your purchase of *akokono* in order to understand its marketability within your communities. This is a research project being conducted by myself, Loloah Chamoun, principal investigator and PhD student at McGill University in Canada and a research assistant from KNUST. It should take approximately 5 to 10 minutes to complete.

Participation:
Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You are free to decline to answer any particular question you do not wish to answer for any reason.

Benefits:
You will receive no direct benefits from participating in this research study. However, your responses may help us learn more about the marketability of *akokono* and whether it could be used as a source of income for you and your peers.

Risks:
There are no foreseeable risks involved in participating in this study.

Confidentiality:
Your survey answers will be stored in a password protected computer and only myself, the principal investigator Loloah Chamoun, and my supervisor, Dr. Hugo Melgar Quinonez from McGill University will have access to them. Your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study.

Consent: Please sign below if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities. A copy of this consent form will be given to you and the researcher will keep a copy.

Participant's signature: _____

Printed name: _____

Date: _____

If you have any questions or concerns about this study, please contact the Principal Investigator, Loloah Chamoun at Loloah.chamoun@mail.mcgill.ca or the Supervisor, Dr. Hugo Melgar-Quinonez at hugo.melgar-quinonez@mcgill.ca
For concerns related to your rights and welfare as a research participant you may contact Lynda McNeil from the Research Ethics Board at McGill University at Lynda.mcneil@mcgill.ca or at (514-398-6831).

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McGill University
Participant Information Letter
COVID-19 and In-Person Research Respecting 2-metre Distancing
(The use of palm weevil larvae in food fortification for women of reproductive age in the Ashanti region in Ghana and REB# 20-01-032)

The health and safety of both research participants and researchers are primary concerns of the University. The purpose of this letter is to provide you with information about COVID-19 and how your study participation may be affected because of COVID-19 related risk. All other information in the study consent remains the same.

Please read the following information to determine if participation is right for you at this time.

The occupational health and safety measures that will be put in place during your study participation have been approved by the McGill Emergency Operations Committee, based on current federal and provincial public health directives as well as recommendations from the World Health Organization (WHO).

What are the risks of COVID-19? For most people, COVID-19 causes mild or moderate symptoms, such as fever and cough. For some, especially older adults and people with existing health problems, it can cause more severe illness, including pneumonia, and, more rarely, may cause death.

Who is most at risk? Persons aged 70 and over, those with a weak immune system and those with a chronic disease such as some cancers, diabetes or heart, lung and kidney disease, are most at risk of developing serious complications if they contract the virus. As per the Directive: Resumption of research with human participants, in-person research involving these vulnerable populations is not allowed at this time in the absence of a strong clinical imperative.

Can COVID-19 be prevented? Current evidence suggests person-to-person spread of COVID-19 is efficient when there is close contact, making physical distancing an important prevention measure. Proper handwashing, cough hygiene and cleaning with an appropriate disinfectant are also key to limiting virus transmission.

It is important to understand that since study participation may include increased travel outside of your home and increased contact with others within a clinical care environment or research site, it may increase your exposure to COVID-19.

What procedures will be in place to minimize risk of transmission of COVID-19 during your study participation?
The assessments of risks and the protocols to mitigate them are guided by the Directive: Preventing the spread of COVID-19 on campus and the Directive: Principles and procedures for research on campus. Measures that will be taken to reduce the risk include:

- maintaining 2-metre physical distancing;
- hand washing before and after study participation;
- providing the participant with a disposable facemask if they do not have one;

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- limiting the number of times a participant has to come to a research site;
- reducing the time participants are in contact with other people;
- ensuring all high-touch surfaces and objects are disinfected daily and disinfected between users.

All research team members are required to have training on preventing the spread of infection and all McGill students and employees must respond each day to a required self-assessment health questionnaire. All participants will be screened before accessing the research site and will be asked if they have symptoms of COVID-19 or have been in close contact with anyone who has or has had COVID-19. Participation will be cancelled or postponed when responding yes to any of the screening questions. Wearing a mask that covers the mouth and nose is mandatory inside all McGill buildings, in accordance with Quebec public health regulations.

By agreeing to participate in this study you acknowledge that you have been informed of the health and safety procedures in place and agree to follow them. Please be reminded that participation is voluntary and you may decline or postpone participation at any time.

There are two ways to acknowledge receipt of this Participant Information Letter. The first and preferred way is digital confirmation (typically email) in advance of the research taking place. The second, acceptable approach is researcher documentation of verbal agreement.

Focus Group Discussion Guide

Project Title: The use of palm weevil larvae in food fortification for women of reproductive age in the Ashanti region in Ghana.

The focus group discussions will examine women's attitudes, beliefs, perceived benefits and acceptance of *akokono* for consumption and sale, as well as their involvement in *akokono*'s farming and sale within their communities. They will also be asked to share some of their knowledge regarding nutrition, their job and food preparation.
The focus group discussion will be semi-structured discussions using open-ended questions. The focus groups will be conducted by X (name of moderator- TBD), X (note taker).

Some possible questions include:

(1) Related to *akokono*:

- Why do you and why don't you consume *akokono?*
- In what forms do you consume it? Which one do you prefer?
- How often do you consume *akokono* and what makes you want to consume it?
- Where do you get your *akokono*, how much do you pay for it and how accessible is it?
- How long does it take you to go buy *akokono*?
- What meals do you cook with *akokono*?
- Would you ever feed *akokono* to your children or household members? Why or why not?
- Would you ever buy a product that contains *akokono*? Why or why not?
- What would it take for you to change your mind about consuming *akokono?*
- In your opinion, what could *akokono* be used for?
- Would you rather eat it or sell it?

(2) Related to working:

- What kind of work do you do?
- Do you like your work? If yes, why? If no, why not?
- What would you prefer to do? Why?
- Where is it located, how do you get there, and how long does it take you to get there?
- How often do you get paid?
- What percentage of your income do you use on food etc. (to determine)?
- Do you manage your own income? If no, who does?
- Do you think that women should manage their own income?
- If you don't work, would you like to work? Why and why not?

(3) Related to nutrition and food preparation:

- Who is in charge of purchasing the food in your household?
- How do you/ they decide what to buy?

- Who is in charge of deciding what to eat?
- How do you decide what to cook?
- Describe a typical mealtime in your household.
- Do the dietary preferences of a particular individual take priority? If so, which individuals have the most influence over what is consumed?
- Which healthy (diverse and nutritious) habits do you try to implement?
- What food do you cook the most and why?
- Which food is your favorite to prepare and why?
- Which food is your favorite to eat and why?
- Do you know what iron is? And what foods contain it?
- What do you do to include iron in your diet/ lifestyle?
- Do you know someone who has had iron deficiency anemia? When they have had it, did they go to the hospital? And what did the doctor say and recommend they did?

Marketability Survey Questionnaire

What age group do you fall into:
[18-24]
[25-29]
[30-34]
[35-39]
[40-44]
[45-49]
[50+]

What is your gender:
Woman
Man

What is the highest educational degree you have obtained:
No degree
Primary school
Secondary school
University degree (1st cycle)
University degree (2nd- 3rd cycles)

What income level do you fall into:
Below 500 GHC/ month
500 to 1500 GHC/ month
1500 to 2000 GHC/ month
2000 to 5000 GHC/ month
5000 to 10000 GHC/ month
Over 10000 GHC/ month

What is your cultural background? What tribe are you from?

Consumer type:
New consumer of *akokono* (first time eating it)
Regular consumer of *akokono* (not the first time eating it)

***Akokono* consumption frequency:**
Daily
Once per week
Twice per week
Three times per week
Once per month
Twice per month

Occasionally

Customer type:
New customer of *akokono* (first time buying it)
Regular customer of *akokono* (not the first time buying it)

***Akokono* purchase frequency:**
Daily
Once per week
Twice per week
Three times per week
Once per month
Twice per month
Occasionally

Form of *akokono* purchased:
Raw
Ground
Fried
Kebabs
Cookies
Other:

Quantity of *akokono* purchased (bring containers to show weight)
<100 g
100-500 g
500-1000 g
>1000 g

Or

Indicate number of skewers or cookies purchased:

Reasons for purchasing *akokono*: (circle one or more answers)
Dietary or health reasons
Food habit/ cultural belief
Flavor
Curiosity of the product
To vary the menu
To sell it
Convenience
Other reasons:

Why do you prefer buying *akokono* when you can harvest it?

Do you believe *akokono* is affordable?
Yes
No
Comment:

Up to how much would you pay for *akokono*?

Where do you purchase your *akokono* from:
Market
If yes, name of market:
On-site at Aspire's farm
Other:

Do you purchase your *akokono* from the same location every time?
Yes
No

How much time does it take you to get from your house to the market:
< 5 mins
5-15 mins
15-30 mins
30-60 mins
>1 hour

How do you get to the market?
Your car
Taxi/ uber
Public transportation
Bike
Foot

Sensory Evaluation Questionnaire

Product: X
Description of product: X
Before trying a sample, clean your mouth by eating a piece of cracker and drinking a sip of water.
Eat the sample with the number **917**, then express your opinion on these attributes:

Color	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Taste	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Mouthfeel	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Texture/ Consistency	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Overall Liking	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much

Do you accept **917** as a product?

Yes	No
If no, please state why:	

Would you purchase **917** as a product?

Yes	No
If no, please state why:	

Knowing that *akokono* has nutritional benefits and could potentially alleviate your malnutrition and iron deficiency, please answer the questions below:
Do you accept **917** as a product?

Yes	No
If no, please state why:	

Would you purchase **917** as a product?

Yes	No
If no, please state why:	

Before trying a sample, clean your mouth by eating a piece of cracker and drinking a sip of water.
Eat the sample with the number **906**, then express your opinion on these attributes:

Color	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Taste	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Mouthfeel	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Texture/ Consistency	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Overall Liking	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much

Do you accept **906** as a product?

Yes	No
If no, please state why:	

Would you purchase **906** as a product?

Yes	No
If no, please state why:	

Knowing that *akokono* has nutritional benefits and could potentially alleviate your malnutrition and iron deficiency, please answer the questions below:
Do you accept **917** as a product?

Yes	No
If no, please state why:	

Would you purchase **917** as a product?

Yes	No
If no, please state why:	

Before trying a sample, clean your mouth by eating a piece of cracker and drinking a sip of water.
Eat the sample with the number **608**, then express your opinion on these attributes:

Color	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Taste	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much

Mouthfeel	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Texture/ Consistency	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much
Overall Liking	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much

Do you accept **608** as a product?

Yes	No
If no, please state why:	

Would you purchase **608** as a product?

Yes	No
If no, please state why:	

Knowing that *akokono* has nutritional benefits and could potentially alleviate your malnutrition and iron deficiency, please answer the questions below:
Do you accept **917** as a product?

Yes	No
If no, please state why:	

Would you purchase **917** as a product?

Yes	No
If no, please state why:	

Sensory questionnaire (socio-demographic)

What age group do you fall into:
[18-24]
[25-29]
[30-34]
[35-39]
[40-44]
[45-49]
[50+]

What is your gender:
Woman
Man

What is the highest educational degree you have obtained:

No degree
Primary school
Secondary school
University degree (1st cycle)
University degree (2nd- 3rd cycles)

What income level do you fall into:
Below l,000 GHC/year
1,000 to 4,000 GHC/year
4,000 to 10,000 GHC/year
Over 10,000 GHC/year

Consumer type:
New consumer of *akokono* (first time eating it)
Regular consumer of *akokono* (not the first time eating it)

***Akokono* consumption frequency:**
Daily
Once per week
Twice per week
Three times per week
Once per month
Twice per month
Occasionally

How important do you think consuming iron is:
Very important
Slightly important
Not important
I don't know

Appendix 2: Supplementary tables

a) Supplemental table 1: Quotes from focus group discussions regarding the barriers and facilitators to consuming *akokono* according to women in peri-urban communities in Ashanti, Ghana
b) Supplemental table 2: Quotes from focus group discussions regarding the barriers and facilitators to purchasing *akokono* according to women in peri-urban communities in Ashanti, Ghana
c) Supplemental table 3: Quotes from focus group discussions regarding women's perceptions of anemia and treatments in peri-urban communities in Ashanti, Ghana
d) Supplemental table 4: Sensory evaluation samples compositions and blinding codes

a) Quotes from focus group discussions regarding the barriers and facilitators to consuming *akokono* according to women in peri-urban communities in Ashanti, Ghana

	CONSUMPTION			
BARRIERS	**Disgust**	**Scarce**	**Unhygienic handling**	**"Unnatural Sourcing"**
	"I don't eat akokono. I can't even stand the sight of them. Their movements make them look disgusting"(Community D)	*"I consume akokono, but if they are sold or distributed under unhygienic conditions, I may change my mind against it." (Community E)* *"The Palm tree is somehow scarce currently, and that has led to the unavailability of the insect." (Community C)* *"At first, we often eat akokono but now we don't get to eat it because of its scarcity." (Community F)* *"We normally consume it but now is very scarce. It is very nice and healthy." (Community F)* *"It is very scarce currently so I don't consume it often." (Community E)*	*"I consume akokono, but if they are sold or distributed under unhygienic conditions, I may change my mind against it." (Community E)*	*"Nothing can really change my mind on its consumption, except it comes from a different source aside the palm tree." (Community E)* *"If I don't see it being sourced from a palm tree, I won't be convinced to consume it." (Community E)* *"If the larvae's source is not from the palm tree, I will start eating them. I feel harvesting them from the palm is not healthy." (Community B)* *"I will keep eating akokono if the source is from the palm tree because of the frequent use of chemicals to grow livestock." (Community B)* *"It is not recommended for my blood group type." (Community D)*

		"Lately, it is very scarce so I hardly eat it." (Community E) *"I haven't eaten akokono since five years ago because it is scarce" (Community D)* *"It is challenging to come by akokono these days. You first need to have access to a decaying palm tree and hope that palm weevils have laid eggs in the palm tree. The distance is however relative. Some are far, and others are close." (Community B)* *"I once ate it in infancy and I liked it but currently it's very scarce." (Community E)* *"If it's not available for a long time, I might lose interest in consuming it." (Community E)* *"If I don't get it daily for consumption, I can lose interest in its consumption." (Community E)*		*"If I don't see it being sourced from a palm tree, I won't be convinced to consume it." (Community E)* *"Nothing can really change my mind on its consumption, except it comes from a different source aside the palm tree." (Community E)*

FACILITATORS	**Natural**	**Treat it like other meats**	**Healthy and nutritious**	
	"I love it because it is natural. Most of the meat we eat from the market has some chemical residues, but it is not so with akokono. It is sourced directly from palm trees which makes its consumption healthy." (Community B)	*"Just like me buying frozen fish and chicken in cold stores, I think I would do same if akokono is frozen." (Community C)* *"Once it is meat, refrigeration does not matter so I will buy." (Community C)* *"I will buy it because it is no different from buying frozen fish." (Community B)*	*"Akokono contains nutrients that protect and keeps your spine strong." (Community E)* *"I eat akokono because I know it is a type of protein, so if my mother prepares a meal with it, I consume it." (Community D)* *"Akokono eaten with fufu and prekese is nutritious and contains adequate protein" (Community D)* *"Akokono contains lots of nutrients. Although I don't know the names of the specific nutrients, I know akokono is very nutritious, and that is why I eat them." (Community B)* *"Akokono is really a nutritious meat so I consume it." (Community C)* *"The health benefits derived from consuming akokono are the sole reason I will recommend it to others." (Community B)* *"I eat akokono because it boosts my blood volume. It also improves my health and wellbeing. I prepare different stews and soups with it and with so much oil oozing out of it, one can tell how nutritious it is." (Community B)* *"Although it is one of the oldest traditional sources of protein, it is tough to rear, but when matured, the*	

			nutritional benefits it provides for the body is worth the trouble." (Community B) *"[Akokono] is a protein source for all kinds of stews and soups" (Community D)* *"[Akokono] is an adequate protein" (Community D)*

b) Quotes from focus group discussions regarding the barriers and facilitators to purchasing *akokono* according to women in peri-urban communities in Ashanti, Ghana

	PURCHASE		
BARRIERS	**Changes in properties due to processing**		
	"I believe that if it is frozen, the taste would change and it wouldn't taste fresh, so I would not buy it." (Community F) *"I don't think I will buy because it wouldn't taste the same as consuming it in its fresh non-frozen form" (Community C)* *"I will not buy because freezing it might cause it to lose its nutritional value". (Community E)* *"I believe when it's stored in a freezer for a while, it loses its nutritional value, so I will prefer it is sold in its fresh or live state. A representative from Donyina can be tasked with the sales" (Community B)*		
FACILITATORS	**Increasing shelf-life**	**Health benefits**	**Increases acceptability**
	"We will buy it in any form of product because the akokono itself is scarce." (Community E) *"I will buy it because first of all it is scarce and keeping them refrigerated will preserve them from going bad, making them available." (Community B)* *"This type of meat is very scarce, so if it is even stored in a freezer*	*"I will buy it. I have already been informed about how healthy and delicious it tastes, and although I have never eaten some, I will like to try it provided, it looks appealing." (Community B)* *"I will buy because I know how nutritious it is." (Community E)*	*"Although I have never eaten akokono, I bought a biscuit made from it. It tasted nice, and for that reason, I will buy any other product that contains akokono." (Community B)*

	and made available, we will buy it." (Community B) *"I will go for it. It's very scarce, so if it can be processed and made available, I will buy it." (Community B)* *"Yes, because cold storage has no harmful effect, rather it would only preserve it." (Community C)*	*"Because we know akokono is good for our health, I will buy frozen akokono from the cold store." (Community F)* *"Since I have eaten it and I know its benefits; I will buy any product made from akokono." (Community F)* *"If it comes to the market and it is made from akokono, I will buy and consume it because it is nutritious." (Community E)* *"We know the nutritional value of akokono so yes, we will buy any product that contains akokono like bread." (Community F)*	

c) Quotes from focus group discussions regarding women's perceptions of anemia and treatments in peri-urban communities in Ashanti, Ghana

	PALM-GROWING COMMUNITIES (PGC)	NON-PALM-GROWING COMMUNITIES (NPGC)
PERCEPTIONS OF ANEMIA	*"I remember taking my anaemic child to the hospital. The doctor did not prescribe any medicine for him. However, he recommended that I add turkey berries and kontomire to the meal I prepare for my son. I did that, and within some few weeks, my child recovered." (Community B)*	*"Yes, my friend was diagnosed with anaemia at the hospital so we gave her kontomire, turkey berries in a milo drink and she recovered." (Community F)*
		"Yes, my daughter was anaemic and I was advised by a neighbour to feed her with turkey berry and milo drink." (Community C)
	"I knew an older adult who was anaemic; he reported to the hospital, and the doctors recommended that he eat a lot of meat." (Community D)	*"Yes, my mother had that condition and was referred to the hospital. The doctor recommended she takes a lot of green leafy vegetables and also unripe pawpaw and with time she was no longer anaemic." (Community C)*
	"My grandmother once had anaemia. We went to the hospital, and the doctor prescribed blood tonic and advised her to eat kontomire." (Community D)	
	"My daughter was diagnosed with anaemia when she went for maternal care, so the doctor gave her some drugs and asked her to eat Kontomire." (Community D)	*"I knew someone who had iron deficiency anaemia. At the hospital, the doctor advised the person to take in more of the natural foods like kontomire and turkey berries which boosts blood levels." (Community B)*
	"Yes, but I can't tell when she had the anaemia, but the health workers advised her to eat more of kontomire, turkey berry and palm oil." (Community D)	*"Yes, [I knew someone with iron-deficiency anemia] he never went to see the doctor. He recovered after being*

"I knew a pregnant lady who was diagnosed with anaemia, and the doctor gave her some drugs and also advised her to eat homemade foods like Kontomire and turkey berries."(Community D)

"She was five years old when she was diagnosed with anaemia, so the doctor advised her to eat kontomire and eggs" (Community D)

"I am aware of anaemia symptoms, and I have also seen people show those symptoms. Weight loss and bloated cheeks, as well as pale skin, are a few of those symptoms. I remember taking my anaemic child to the hospital. The doctor did not prescribe any medicine for him. However, he recommended that I add turkey berries and kontomire to the meal I prepare for my son. I did that, and within some few weeks, my child recovered." (Community B)

"When you want a child to recover from anaemia, they must be fed with stews or soups prepared with kontomire and turkey berries." (Community B)

"There are other leafy vegetables aside from kontomire which are rich in iron. In the past, we prepared soups with the bark of a particular tree known as Apatra. You add this bark to your kontomire soup containing turkey berries and other herbs and fed with blended turkey berry, and fish." (Community E)

"Yes, [I knew someone with iron-deficiency anemia] he was 17 years old. He went to see the doctor and was recommended to blend and drink turkey berry." (Community E)

"Yes, I once had iron deficiency anaemia. I received a blood transfusion and was advised to eat iron-based food like kontomire and turkey berries." (Community F)

"Yes, my sister had iron deficiency anaemia. After she came back from the hospital, we feed her with food containing turkey berries, kontomire and palm oil for some time and she recovered" (Community F)

"My grandchild was diagnosed with anaemia and the doctor said I should blend dry kontomire and mixed it with any food for him to eat." (Community F)

"My child got sick and the doctor said that she has anaemia, so he advised that she drinks malt drink mixed with milk." (Community F)

"When my son was sick and diagnosed with low blood levels, the doctor advised that I fed him with more turkey berries and tomatoes."(Community F)

	give it to your anaemic child. That child is bound to recover after drinking that soup. Other herbs like cassava leaves are also rich in iron. You don't need to take your child to the hospital. Just prepare some soup with these herbs, and he or she will be fine." (Community B) *"An anemic person is one whose blood level is low. Doctors normally recommend blood tonics to such individuals to help boost their blood volume." (Community B)* *"One of my grandchildren was not well. His palm, eyes and skin looked pale. He couldn't sleep at night. I took him to the hospital, and the doctor said he was anaemic. I mixed a cocktail of herbs, including turkey berries and malt drink and gave it to him. My grandchild recovered after some few days." (Community B)* ***"**My pregnant daughter, after going for a check-up was diagnosed with anaemia. I then prepared a milk-turkey berries-drink for her and she drank it. When delivery time was due, her labs were done again and she was no longer anaemic." (Community B)*	*"My child was diagnosed with low blood, and I was advised to boil turkey berries, add it to a milo drink and feed him with it. It worked wonders and in just a week he was fine and is blood level shot up." (Community F)* *"Yes, they recommended for her to add a lot of green leafy vegetables and beans in her diet." (Community C)*
HOUSEHOLD-MAKING DECISIONS	*"I give my children the opportunity to decide what will be eaten at home." (Community E)*	

AROUND FOOD	*"My children and grandchildren decide what they would want to eat and I provide". (Community F)* *"The available money I have on me is what I decide on to determine what to cook." (Community F)* *"When I farm, the produces available determines what I would cook." (Community F)* *"My decision on what to cook is based on my finances." (Community B)* *"I am the one in charge of deciding what should be eaten because I provide the cash." (Community B)* *"My husband is the decider because he provides the cash." (Community B)* *"My husband is in charge, but I sometimes support him by adding up to the money he gives." (Community B)*

d) Sensory evaluation samples compositions and blinding codes

Sample composition	**Blinding codes**	**Sample name**
Akokono paste 15%	553	A
Akokono paste 30%	236	B
Akokono paste 8%	584	C
Akokono sauce 15% + rice	201	D
Akokono sauce 30% + rice	369	E
Akokono sauce 8% + rice	388	F