UNIVERSITY OF CAPE COAST

NUTRITIONAL ANALYSIS OF FORMULATED INFANT FOOD USING SWEET POTATOES, SOYBEANS, AND SHRIMP

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BY

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Thesis submitted to the Department of Vocational and Technical Education of the Faculty of Science and Technology Education, College of Education Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy Degree in Home Economics.

FEBRUARY, 2025.

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my original investigation and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature ………………………… Date……………………..

Name: Melody Dumagu

Supervisor's Declaration

I hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on thesis supervision established by the University of Cape Coast.

Principal Supervisors Signature ………………… Date ……………………

Name: Prof. (Mrs.) Sarah Darkwa

ABSTRACT

This study explores the utilisation of soybean flour, orange-fleshed sweet potatoes, and shrimp in infant food, as well as a small addition of tomatoes and onions. Soybean seeds, orange-fleshed sweet potatoes, shrimp, tomatoes, and onions were processed into powder. To achieve the various formulations, Minitab software was used: 80%:10%, 78%:12%, 75%:15%, 72%:18%, and 70%:20% of soybean and orange-fleshed sweet potato composite flour. Also, 10% shrimp, 5% tomatoes, and onion powder were added, and 100% OFSP was used as a control sample. Quality indicators like functional properties, nutritional composition, mineral content, and consumer acceptability of the infant food developed thereof were determined. Finally, the bulk density decreases from (0.69g/cm^3 to 0.63g/cm^3, while swelling capacity, water absorption capacity, oil absorption capacity, and solubility index increase from (16.83 to 17.89), (214.85% to 244.07%), (217.33% to 255.49%), and (16.31 to 18.15). Increasing the soybean flour fortification from 70% to 80% in infant food significantly increases the moisture content (8.78% to 10.39%), protein (25.25% to 33.11%), and fibre (7.56% to 8.87%) while decreasing the carbohydrate content from (43.19% to 27.65%) respectively. There was an improvement in the mineral content (phosphorus, iron, potassium, and zinc) of the orange-fleshed sweet potato soybean flour-fortified infant food. Furthermore, vitamin C significantly increased, and beta-carotene decreased with an increase in the inclusion of soybean flour in the infant food. Moreover, consumer acceptability of the infant food was enhanced after the soybean flour was added. These results may be relevant for improving the utility of soybean flour and orange-fleshed sweet potato, shrimp, and onion in the food industry.

KEYWORDS

Consumer acceptability

Infant Food

Nutritional composition

Orange-fleshed sweet potato

Soybean flour

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DEDICATION

To my parents and entire family

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LIST OF ABBREVIATIONS

OFSPF	Orange-fleshed sweet potato Flour
ONF	Onion Flour
SBF	Soybean flour
SPF	Shrimps Flour
TMF	Tomatoes Flour

CHAPTER ONE

INTRODUCTION

Background to the Study

The study of nutrients found in food, how the body uses them, and the relationships between diet, health, and illness is known as nutrition (Newman et al., 2020). According to the author, nutrition also emphasizes how individuals can lower their risk of disease by dietary choices. Nutritional analysis is the process of determining a food's nutritional worth (Anfossi et al., 2019). The author claims that nutritional analysis, which provides information on food contamination, quality control, processing, and chemical composition, is a crucial part of analytical chemistry. It ensured adherence to commerce and food rules (Anfossi e, 2019). During the first 12 months of a baby's life, infant formula, a unique dried milk powder, is used in place of or in addition to breast milk. Infant formula aims to give a newborn all the nutrients they require, including protein, carbs, and fats, and is designed to mimic breast milk as much as possible.

Ipomoea batatas, the scientific name for sweet potatoes, is an important staple crop and a crucial commodity for global food security, especially in sub-Saharan Africa (Aparecida Pereira et al., 2019). It is well-known for its many health advantages, such as increasing blood sugar regulation, raising vitamin A levels, and reducing the risk of certain types of cancer (Mohanraj & Sivasankar, 2014). Some varieties of sweet potato are rich in ß-carotene, a precursor to vitamin A, as noted by Mohanraj and Sivasankar (2014). Orange-fleshed sweet potato is ranked as one of the most competent plant sources of β-carotene, the provitamin A (Neela & Fanta, 2019). Because of its high ß-carotene concentration, the orange-fleshed sweet potato was selected for this study as a viable crop to help Ghanaian children who are vitamin A deficient (Neela & Fanta, 2019).

A significant food crop high in protein and vegetable oil is the soybean (Glycine max) (Sugiyama et al., 2015). Alpha-linolenic acid and the vital omega-3 fatty acid are reportedly found in sufficient proportions only in soybeans (Messina & Messina, 2010). Furthermore, soybeans have more biotin, a nutrient that is known to be essential, than vegetables and meat items (Saidaiah et al., 2024). Phytochemicals such phenolic compounds and isoflavones (Kim et al., 2017) found in soybeans are good for human health (Tyug et al., 2010).

A shrimp is a kind of crustacean, or shellfish, with an extended body that moves mostly by swimming. Although other crustaceans outside of the Decapoda order are also referred to as "shrimp," it usually belongs to the Caridea family (Ja et al., 2024). According to more precise definitions, the name might only refer to maritime species, smaller species of either group, or only Caridea. In broader terms, shrimp can be synonymous with prawn, referring to stalk-eyed swimming crustaceans with long, narrow muscular tails (abdomens), long antennae, and slender legs (Ja et al., 2024). Shrimps are widely distributed and abundant, playing crucial roles in the food chain, serving as a vital food source for larger animals, from fish to whales. The muscular tails of many shrimp are edible and are extensively caught and farmed for human consumption. According to Ja et al. (2024), the commercial shrimp industry generates an annual value of 50 billion dollars.

Shrimps contain essential nutrients and amino acids and contribute to improving human health (Nesara & Anand, 2018). Despite the nutritional qualities of shrimp, exploring its food uses is still low in most low-income nations. Thus, incorporating shrimp in infant food would be relevant for enhancing the nutritional composition, although it has not been explored.

Statement of the Problem

Complementary feeding is a vital phase in an infant's development, as it provides the nutrients that breast milk alone can no longer supply. In Ghana, complementary foods are commonly prepared from grains or mixtures of grains and legumes (Apolala, 2021). However, many mothers may lack adequate knowledge of how to combine different foods to provide their infants with the necessary nutrients for healthy growth. As a result, a number of studies have highlighted the risk of stunted growth for children who eat supplemental foods lacking in essential nutrients such proteins, vitamins, minerals, and carbs (Ogunlesi et al., 2014).

Nevertheless, affordable and locally available food options, when appropriately combined, can meet infants' nutritional needs. Examples of such foods include potatoes, soybeans, and shrimp. A significant proportion of children aged 6–24 months in Ghana suffer from anemia and stunting, with notable regional variations in prevalence (Anane, 2020). This situation represents a serious public health concern, as the prevalence exceeds ten percent, and the coexistence of stunting and anemia substantially increases the risk of childhood morbidity and mortality.

According to Asare et al. (2022), the Pokuase Municipality and the Greater Accra Region continue to have subpar exclusive breastfeeding and timely supplemental feeding habits. Inadequate nutrient intake and the expensive expense of some current supplemental foods are frequently blamed for this deficiency. Conversely, complementary foods made from local ingredients have been shown to help reduce stunted growth and anemia among infants. For example, soybean protein is recognized as a good substitute for animal protein, providing a nearly complete amino acid profile (except methionine) as well as a range of water- and fat-soluble vitamins (Lokuruka, 2010; Rizkiyanda et al., 2024).

Similarly, sweet potatoes are low-calorie, fat-free tubers rich in beneficial nutrients such as beta-carotene, vitamins A, C, and E, magnesium, and antioxidants, yet they remain underutilized in many African countries.In the same way, shrimp is a nutrient-rich food that provides significant amounts of vitamin B12, zinc, iodine, phosphorus, potassium, and other essential minerals; however, its potential use in infant food formulations has not been fully explored.

Malnutrition among infants thus remains a persistent public health challenge in Ghana, particularly in the form of stunting and anemia among children aged 6–24 months. Despite ongoing national and regional nutrition initiatives, many infants continue to receive complementary foods that fail to meet their nutritional requirements. In the Pokuase Municipality, as in other parts of the Greater Accra Region, these challenges are compounded by limited knowledge of appropriate food combinations and the high cost of commercially available complementary foods (Asare et al., 2022).

Although local food resources such as soybeans, sweet potatoes, and shrimp are rich in proteins, vitamins, and minerals, their potential for use in developing affordable, nutritionally balanced complementary foods remains largely untapped. Most existing studies and interventions have focused on cereal-based or legume-only formulations, with limited exploration of nutrient-dense, multi-ingredient blends capable of addressing both protein and micronutrient deficiencies.

This gap underscores the need to develop and evaluate complementary food products made from affordable, locally available ingredients that can provide adequate nutrition for infants. Therefore, this study seeks to formulate and assess a composite complementary food using potatoes, soybeans, and shrimp, with the goal of improving infant nutrition and reducing the prevalence of stunting and anemia among children in the Pokuase Municipal area.

Purpose of the Study

The main purpose of the study was to develop and assess the impact of Soybean flour fortification on the nutritional and sensory attributes of orange-fleshed sweet potatoes-shrimp infant food

Specific Objectives

The specific objectives were to:

1. develop a composite infant food from different proportions of sweet potatoes, soybeans, and shrimp.
2. determine the impact of soybean flour fortification on the functional properties of the developed composite flour.
3. determine the effect of soybean flour fortification on the nutritional composition, vitamin C, and beta-carotene content of the developed infant food.

4. evaluate the sensory characteristics of the developed baby food product.

Research Hypotheses

1. There is no statistically significant difference between the functional properties of the fortified developed baby food product and non-fortified flour.
2. There is no statistically significant difference between the nutritional composition of the fortified developed baby food and non-fortified flour.
3. There is no statistically significant difference among the sensory attributes of the various proportions of fortified composite baby food.

Significance of the Study

The study would help (NGOs), manufacturing firms, communities, researchers, Ghana Health Service, and other policymakers. The findings may serve as reference material for households, companies and community initiatives to produce nutrient-rich formulated infant foods aimed at reducing malnutrition and anemia among infants in Ghana, particularly in the Pokuase Municipality, where these issues are prevalent. It is hoped that these new products will contribute to lowering the ongoing rates of stunting and anemia among infants in the Greater Accra Region.

The ingredients (sweet potatoes, soybeans, and shrimps) used in producing the formulated infant food are underutilized, and if accepted could ...support the promotion of these locally grown food items, making it easier for mothers to access and use them to nourish their babies for healthy growth and development.

Delimitations

Although various complementary foods already exist, this study specifically concentrated on developing an infant food using potatoes, soybeans, and shrimp flour. It was a hospital-based study carried out among infants aged 6 to 24 months attending a child welfare clinic.

Organization of the Study

This study is organised into five chapters. The first one, which is the introductory chapter, comprises background of the study, the problem statement and the research objectives, the significance of the study, the scope and limitations of the study, as well as the organisation of the study. Chapter two, the literature review, focused on reviewing relevant literature concerning the study. Specifically, the theoretical underpinnings and the empirical support as well as the conceptual framework designed for the study. Chapter three covers the research methods used for the study covering the research design, study area, source of data and analysis. Chapter Four was devoted to the detailed analysis of the results as well as a discussion of findings. Finally, the study's findings were summarized in chapter five, which also included conclusions and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Chapter Two presents the theoretical framework, concepts, and empirical review of existing information concerning the study. It includes the conceptual review, theoretical review, empirical review, and conceptual framework on the nutritional analysis of formulated infant food using sweet potatoes, soybeans, and shrimp.

Origin and Distribution of Orange-Fleshed Sweet Potato

According to Tanaka et al. (2017), the sweet potato (Ipomoea batatas L) is believed to have originated in Central America. According to Neela and Fanta (2019), the crop was probably brought to the Caribbean and South America by indigenous peoples as early as 2500 BC. Sweet potatoes were later introduced to Africa by Spanish and Portuguese explorers (Smith et al., 2022). Today, the crop is grown in both tropical and warm temperate regions. Presently, sweet potatoes are grown widely across tropical regions, including in Ghana (Sapakhova et al., 2023). According to Hu et al. (2025), China accounted for the majority of global sweet potato production—approximately 80%—between 2006 and 2010, followed by countries such as Indonesia, Vietnam, India, Japan, and the Philippines. In Africa, annual sweet potato production amounts to around 11.6 million tons.

Cultivation of Sweet Potato

Sweet potato, scientifically known as *Ipomoea batatas*, is a tuberous crop belonging to the Convolvulaceae family. While there are around 400 species within the *Ipomoea* genus, only *Ipomoea batatas* produces edible roots suitable for human consumption (Smith et al., 2022). Although it is a perennial plant by nature, sweet potato is typically cultivated as an annual crop. It is propagated either asexually through vine cuttings or sexually through seeds (Mulovhedzi et al., 2020).

Sweet Potato Varieties

Sweet potato types vary in their nutrient content depending on a number of factors, including soil composition, climate, and crop variety (Adekambi et al., 2020). Cream, yellow, orange, and purple blooms are also produced by it (Smith et al., 2022). Sweet potatoes are more resistant to diseases, pests, and excessive moisture than many other green vegetables that are commonly grown in tropical regions, according to Smith et al. (2019). Additionally, they can provide a good yield even in the face of difficult weather circumstances and low soil fertility (Smith et al., 2022). Usually tapering and elongated, the edible tuber has smooth skin that might be red, purple, brown, or beige (Mulovhedzi et al., 2020).

Sweet Potato Production in Ghana

Ghana is a West African country whose GDP is largely derived on agriculture (Dittoh et al., 2017). About 40% of this comes from roots and tubers, and about 7% comes from cereals. After cassava, yam, and cocoyam, sweet potatoes are the fourth most significant root crop in the nation (Nanbol & Namo, 2019). Except for the Western Region, it is grown in almost every part of Ghana. With 34.9% of the country's total production, the Upper East Region leads the way, followed by the Eastern Region (26.4%) and the Upper West Region (14.8%) (Smith et al., 2019). In contrast, the Greater Accra and

Ashanti Regions contribute the least to sweet potato production (MoFA & SRID, 2012).

Each year, approximately 90,000 tonnes of sweet potatoes are harvested in Ghana's tropical zones (Nanbol & Namo, 2019). Despite its widespread cultivation, sweet potato has yet to become a significant part of the average Ghanaian diet (Aidoo et al., 2019). The orange-fleshed variety of sweet potato holds particular importance in the Northern and Coastal areas, where it serves as both a food source and a cash crop (Smith et al., 2019). Most of the cultivation is carried out by smallholder, subsistence farmers, typically without the use of fertilizers or other inputs (Smith et al., 2022).

Post-harvest Storage of Sweet Potatoes

Many crops face challenges after harvest due to inadequate post-harvest practices such as exposure to extreme temperatures, poor handling, and chilling injuries. Sweet potato roots, once harvested, are typically stored in sacks within rooms or in pits (Sugri et al., 2020). According to research by Sugri et al. (2020), sweet potatoes generally have a shelf life of about two weeks. Harvested tubers are traditionally preserved in trenches lined with dried grass, covered with another layer of grass and at least five centimeters of dirt, or in baskets covered with banana leaves. Although this pit storage technique can keep the tubers fresh for up to four months, problems like rotting and rodent infestation frequently make it difficult (Sugri et al., 2020). To avoid major moisture loss from the roots, the Department of Agriculture, Forestry, and Fisheries (DAFF, 2023) advises keeping storage temperatures between 12 and 15 °C and relative humidity levels between 75 and 80%.

Economic and Food Uses of Sweet Potato

Sweet potato plays a vital economic role globally by contributing to improved living standards. It is recognized as the seventh most important food crop in the world, following rice, wheat, Irish potatoes, maize, yams, and cassava (Truong et al., 2018; Hue & Low, 2015). In developing countries, sweet potato is especially valuable, ranking among the top ten essential food crops (Truong et al., 2018). Worldwide, approximately 133 million tonnes of sweet potatoes are produced each year (Onuwa, 2022).

In Sub-Saharan Africa, sweet potato is among the most widely cultivated root crops (Truong et al., 2018), providing a major source of food, particularly in tropical regions where most of the crop is grown and consumed (Hue & Low, 2015). According to Smith et al. (2022), in Asia, more than half of sweet potato production is used for animal feed, whereas in Africa, it is predominantly consumed by humans. Beyond food, sweet potato has a wide range of industrial uses (Dereje et al., 2020). For instance, in Nigeria, orange-fleshed sweet potato (OFSP) is processed into flour, which commands higher prices than flour made from other varieties (Odebode, 2010). Sweet potato flour serves multiple functions—it acts as a stabilizer and is used to enrich local beverages like Kunu-Zaki and burukutu, as well as in infant food formulations (Dereje et al., 2020).

In Uganda, the roots are processed into dried chips (Hue & Low, 2015), while sweet potato flour is widely utilized in various food products such as bread, noodles, and as an ingredient in industrial starch and alcohol. It also functions as a thickener, emulsion stabilizer, water binder, and gelling agent (Eleazu & Ironua, 2015). The starch derived from sweet potatoes finds application in industries such as textiles, paper, cosmetics, adhesives, and insulation. The flour is also a key ingredient in many baked and processed goods, including cakes, cookies, biscuits, doughnuts, porridge, cold sauces (e.g., soy sauce and ketchup), and brewing additives (Dereje et al., 2020).

Orange-fleshed sweet potatoes are also valued for their vibrant color due to high β-carotene levels, making them suitable as natural food dyes (Dereje et al., 2020). In Asia, roughly half of sweet potatoes are fed to livestock (Sugri et al., 2020), while in Nigeria and Uganda, sweet potatoes are consumed in diverse forms: boiled, roasted, fried as chips, or processed into chapattis, mandazi, and buns (Dereje et al., 2020). In Ghana, the tubers are commonly boiled and eaten with stew (as “ampesi”), deep-fried as snacks, or mashed to make a traditional Akan dish known as “oto” (Truong et al., 2018). Research by Abong et al. (2016) has shown that varieties such as "Santom Pona" and Hi-Starch, grown in Ghana, can also be used to prepare gari.

Nutritionally, sweet potatoes are considered highly valuable, often surpassing other carbohydrate-rich foods in terms of their content of vitamins, minerals, protein, and energy (Abong et al., 2016). They are a good source of essential nutrients like calcium, potassium (Antonius, 2024), fiber, antioxidants, starch, and vitamins A and C (Zhao et al., 2024). The high fiber content helps promote a feeling of fullness, supports digestive health, and can reduce cholesterol levels. Although rich in carbohydrates, sweet potatoes have a low glycemic index, which slows carbohydrate digestion and sugar absorption into the bloodstream (Zhao et al., 2024). Regular consumption may reduce the risk of constipation, diverticulosis, colorectal cancer, and obesity (Panda et al., 2015). Some studies have shown that sweet potato leaves have nutritional value comparable to spinach (Abong et al., 2016). OFSP, in particular, is rich in dietary fiber, vitamins, minerals, and antioxidants such as phenolic acids, anthocyanins, and tocopherol (Dereje et al., 2020).

Consuming OFSP regularly has been shown to significantly improve vitamin A levels in children (Abong et al., 2016). In Kenya, for example, the inclusion of OFSP in diets led to better vitamin A intake among women and children (Neela & Fanta, 2019). The high β-carotene content makes OFSP a valuable tool in combating vitamin A deficiency (VAD) in many developing countries. As such, incorporating it into complementary foods can boost their nutritional profile (Neela & Fanta, 2019). According to Truong et al. (2018), sweet potatoes may also serve as a beneficial alternative to traditional cereal-based infant foods, offering superior nutritional benefits. These nutritional attributes make sweet potato a strong candidate for enhancing the nutrient quality of food products.

Soybeans and Their Nutritional Importance

Soybeans (*Glycine max*) are a versatile and globally significant crop, valued for their high protein and oil content (Saha & Mandal, 2019). Soybeans were first introduced to Ghana (then the Gold Coast) in 1909. The primary aim was to encourage farmers to adopt soybeans as an additional food source and as a means to improve soil fertility through crop rotation. Despite these intentions, early adoption was limited due to factors such as lack of awareness, limited market demand, and unfamiliarity with processing methods. (soyinfocenter.com) Soybeans are rich in protein (approximately 42–45%), edible oil (around 22%), and carbohydrates (24–26%) (Saha & Mandal, 2019). They also contain essential amino acids, unsaturated fatty acids, and carbohydrates, making them a cholesterol-free dietary staple. The presence of isoflavones and other bioactive compounds in soybeans contributes to various health benefits, including potential roles in reducing the risk of certain diseases cardiovascular disoder.

Soybeans are usually treated before eating because of antinutritional agents like trypsin inhibitors. Tofu, soy milk, tempeh, and soy protein isolates are examples of common products. Additionally, soybeans contain a variety of phytosterols, mainly brassicasterol, campesterol, and stigmasterol, which are useful building blocks for the synthesis of steroid hormones. Group A, which has a bitter taste, and group B, which is recognized for its health-promoting properties, are the two primary categories of soy saponins (Saha & Mandal, 2019). They are frequently utilized to make meat alternatives. Consuming soy products on a daily basis can supply about 25–40 mg of isoflavones, which have been linked to a number of health advantages (Hailu, 2022). Soybean seeds are also used for food, animal feed, and oil production. (Saha & Mandal, 2019). Nonetheless, its primary benefits include being a rich source of protein, essential nutrients, minerals, and insoluble fiber. Over the years, soybeans have been transformed into a diverse range of popular soy-based products.

SHRIMPS

Shrimp, a popular seafood worldwide, is recognized for its high nutritional value and significant contribution to both human health and the global economy. Belonging to the order *Decapoda*, shrimp are widely harvested from both marine and freshwater environments and are also farmed extensively in aquaculture systems. Shrimp is one of the most valuable traded seafood commodities globally according to De-Souza (2021).

Nutritional Value and Health Benefits of Shrimps

Shrimp continues to be recognised for its high-quality protein and essential micronutrients, including selenium, iodine, vitamin B12, and omega-3 fatty acids. Despite its cholesterol content, recent studies indicate that shrimp has a minimal effect on blood cholesterol levels, making it a heart-healthy protein choice when prepared appropriately (Chakraborty, 2025)

Processing and Utilization of Shrimp

Shrimp is highly perishable and requires careful handling and processing to ensure safety and quality. Processing methods include freezing, drying, boiling, and canning. Innovative technologies have been explored to enhance shelf life and reduce waste. For example, modified atmosphere packaging (MAP), vacuum packaging, and edible coatings have shown promise in preserving shrimp quality during storage (Arancibia et al., 2015).

Health Benefits and Nutritional Value of Tomatoes

Tomatoes (*Solanum lycopersicum*) are native to western South America and Central America. They were domesticated in Mexico and spread globally following the Columbian exchange in the 16th century (Borovsky et al., 2019). Initially cultivated as ornamental plants in Europe, tomatoes are now a staple in diets worldwide and widely grown in tropical and temperate climates.

Nutritional Value

Tomatoes are considered a nutrient-dense food. According to Bhowmik et al. (2012) and reaffirmed by more recent studies (Martí et al., 2019), tomatoes are rich in essential vitamins and minerals including. Vitamin C: Boosts the immune system and aids in collagen formation, Vitamin A (as β-carotene**)**: Supports vision and skin health. Vitamin K**:** Important for blood clotting and bone health, Potassium: Helps regulate fluid balance and nerve signals. They also contain dietary fibre and have a low-calorie content (about 18–22 kcal per 100 g), making them beneficial for weight management.

Health Benefits of Tomato

Tomatoes are renowned for their high antioxidant content, particularly lycopene, a carotenoid linked to numerous health benefits, Cancer prevention: Lycopene is associated with a lower risk of prostate, lung, and stomach cancers (Story et al., 2010).,Cardiovascular health**:** Regular tomato intake helps reduce LDL cholesterol and blood pressure (Canine-Adams et al., 2005, cited by Research Gate, 2024), Skin protection: Lycopene protects against UV-induced skin damage and aging (Stahl & Sies, 2012)., Anti-inflammatory effects: Polyphenols and flavonoids in tomatoes reduce inflammation (Martí et al., 2019)., Blood sugar regulation: The chromium and fibre content in tomatoes can help stabilize blood sugar levels, benefiting diabetics.

A 2022 review published in the *International Journal of Molecular Sciences* highlighted tomatoes' role in mitigating oxidative stress and improving metabolic health (Leichtle et al., 2025). The heat-processing of tomatoes (e.g., in sauces) enhances the bioavailability of lycopene, increasing its antioxidant effects. The vitamin A in tomatoes supports good vision and may help prevent night blindness, while also promoting shiny, healthy hair.

Moreover, the chromium in tomatoes supports blood sugar regulation, making them a good choice for people with diabetes. Their high water and fibre content help prevent constipation, promote hydration, and support healthy digestion. Fiber adds bulk to stool, aiding in regular bowel movements. Tomatoes are also a valuable source of folic acid, which is especially important for pregnant women. Adequate folate intake before and during pregnancy helps prevent neural tube defects in newborns. Folic acid, the synthetic form of folate, is commonly taken as a supplement (Cardona & Ambrose, 2020).

ONIONS

Nutritional and Health Benefits of Onion

Onions (*Allium cepa L.*) are among the oldest cultivated vegetables, with evidence of use dating back over 5,000 years. They are believed to have originated in Central Asia, particularly Iran and Pakistan, and were widely cultivated in ancient Egypt, where they were valued both as food and for their supposed spiritual significance (Brewster, 2008). From there, onion cultivation spread through Europe, Africa, and Asia, becoming a staple in cuisines worldwide. Modern onion cultivation is global, with leading producers including China, India, and the United States (UNICEF, 2021). Onions are adapted to various climates and are grown for their bulbs, which store well and are rich in flavour and nutrients.

Nutritional Value of Onions

Onions are low in calories but rich in nutrients, especially vitamins, minerals, and antioxidants. According to Bhattacharjee et al. (2013), 100g of raw onions provide, Energy: 31 kcal, Protein: 1.5 g, Fat: 0.6 g, Carbohydrates: 7.5 g (including 7.2 g sugars), Vitamin C: 7 mg, Potassium: 150 mg, Magnesium: 16.5 mg, Iron: 0.5 mg and 7 mg of sodium. Onions are a source of flavonoids (especially quercetin), organosulfur compounds, and prebiotic fibers (Sharma et al., 2020). Red and yellow onions generally have higher antioxidant activity compared to white varieties.

Although it contains no vitamin A, it offers small amounts of thiamine (0.04 mg), riboflavin (0.02 mg), and niacin (0.1 mg). Studies have shown that *Allium* species, such as onions, have properties that can help inhibit tumour growth, combat cardiovascular diseases, slow aging, and neutralize harmful free radicals (Bhattacharjee et al., 2013). The sulfur compounds in onions are especially beneficial for heart health, as they may help lower the risk of cardiovascular disease.

According to Ozougwu (2011), onions also help reduce high blood sugar (hyperglycaemia) and high cholesterol levels (hyperlipidaemia). This suggests that incorporating onions into children's complementary foods can support better health outcomes, provided they are included consistently in their diet. Bhattacharjee et al. (2013), also conducted a physio-chemical analysis of onion seeds, revealing that they contain a high oil content (ranging from 21.86% to 25.86%) and a significant amount of crude protein (15.7% to 26.1%). Gas chromatography (GC) analysis indicated that onion seed oil is particularly rich in linoleic acid (49.42% to 60.66%), along with notable amounts of oleic and palmitic acids. Similarly, research by Dine, Tenore and Dine (2008) on red onion seeds found they contained 10.5% moisture, 20.4% oil, and 24.8% crude protein. While onion bulbs are known to contain cysteine derivatives—compounds that contribute to their status as a functional food—the seeds have only small amounts of these substance

Health Benefits of Onions

Research has consistently shown that onions possess various health-promoting properties due to their bioactive compounds, particularly organosulfur compounds and flavonoids**.** Onions contain quercetin and other polyphenols that neutralize free radicals and reduce inflammatory markers, helping prevent chronic diseases such as cancer and cardiovascular conditions (Huang et al., 2021). Sulfur-containing compounds in onions help reduce blood cholesterol levels, lower blood pressure, and prevent blood clot formation (Ozougwu, 2011). Regular consumption is associated with a decreased risk of heart disease.

Studies indicate that high consumption of allium vegetables, including onions, is linked to a lower risk of several types of cancer, particularly gastric and colorectal cancers (Dalmartello et al., 2022). Onion extracts have shown potential in lowering blood sugar levels and improving insulin sensitivity in both human and animal studies (Bhattacharjee et al., 2013). Onions exhibit antimicrobial properties due to sulfur compounds like **allicin**, which inhibit the growth of harmful bacteria and fungi (Dine Tenore & Dine, 2008).

Onion Varieties and Composition Differences

Different varieties of onions (red, white, and yellow) differ in their phytochemical content, flavor, and nutritional profile. Red onions, for instance, tend to have higher anthocyanin and quercetin content, while white onions are milder and have lower antioxidant levels (Mulovhedzi et al., 2020).

Complementary Foods

After six months of exclusive breastfeeding, breast milk alone no longer meets the full nutritional needs of infants, leading to a widening nutritional gap as they grow older (Abeshu et al., 2016). To fill this gap, complementary feeding becomes essential. Complementary foods—defined as foods and liquids other than breast milk or infant formula given to infants from six months of age—serve both nutritional and developmental purposes and facilitate the shift from milk feeding to family diets (Abeshu et al., 2016). According to UNICEF (2021), these foods should be energy-dense, rich in high-quality protein containing essential amino acids, and provide necessary vitamins (A, C, and K) and minerals, while being free from anti-nutritional factors and still palatable. The role of complementary foods is vital in supporting children's development (Gehrig et al., 2019).

Abeshu et al. (2016) emphasized that complementary foods must have adequate nutritional content and caloric density to supplement breast milk for infants and support the transition to family foods in toddlers. As infants grow, their nutritional requirements increase, making energy- and nutrient-dense complementary foods essential (Umeta et al., 2003). Prasad and Kochhar (2016) suggest that ideal complementary foods should be nutritionally rich, easy to digest, appropriately textured, and affordable. Poor-quality complementary feeding can lead to stunted growth, which becomes increasingly difficult to reverse after the age of two (Akoto et al., 2015). The type and quality of foods fed to infants significantly affect brain development, especially as the brain undergoes rapid growth from five months before birth to ten months after. By the first year, the brain reaches about 70% of its adult size (Akoto et al., 2015).

Complementary foods must provide sufficient energy: 200–333 g/day for children aged 6–8 months, 300–500 g/day for those aged 9–11 months, and 550–917 g/day for children aged 12–23 months (Abeshu et al., 2016). A lack of energy-dense foods can result in protein-energy malnutrition (Alvisi et al., 2015). Protein is crucial in these foods, not only for providing essential amino acids but also as an energy source during deficiencies (Abeshu et al., 2016). Based on standard breast milk intake, protein requirements from complementary foods are 1.9 g/day for infants aged 6–8 months (21% of their need), 4.0 g/day for 9–11 months (42%), and 6.2 g/day for 12–23 months (57%) (Dewey, 2001).

Fat also plays a significant role in infant nutrition by supplying essential fatty acids, supporting the absorption of fat-soluble vitamins (A, D, E, and K), improving energy density, and enhancing taste and texture (Alvisi et al., 2015; Mitchell, 2011). However, excessive fat can cause rancidity due to oxidation, reducing the shelf life of products (Lohia & Udipi, 2015). Too much fat may also lead to health issues such as obesity, cardiovascular disease, or micronutrient malnutrition (Das et al., 2019).

Fibre provides several health benefits, especially as infants grow, but must be introduced carefully. Though crude fibre doesn't offer nutritional value, it aids digestion and prevents gastrointestinal issues (Das et al., 2019). Ojuri et al. (2018) noted the importance of exposing infants early to a variety of food tastes, including dietary fibre, while cautioning that high fibre intake may reduce overall nutrient intake due to satiety and limited stomach size.

Overconsumption can lead to decreased appetite, excessive gas, or gut irritation (Abeshu et al., 2016; Asma et al., 2006). Low-fibre diets are preferable early on to encourage adequate nutrient consumption (Ijarotimi & Keshinro, 2013).

Ash content reflects the mineral content of foods, which is vital for bone development, nerve function, immunity, and overall body performance in young children (Kavitha et al., 2014; Ojuri et al., 2018). Moisture content is another critical factor, as high levels can promote microbial growth and reduce shelf life. According to Alvisi et al. (2015), moisture content over 14.5% encourages spoilage, while Ojuri et al. (2018) recommend keeping moisture below 13% for safer storage. Das et al. (2019) suggested that ideal complementary foods should contain at least 15% protein and between 10–25% fat. Since cereals are often deficient in vitamins A and C, roots and tubers like sweet potatoes present a valuable alternative due to their affordability, availability, and nutritional benefits (Adenuga, 2010).

Nutritional Composition of Complementary Foods

Various studies have formulated and analysed complementary foods using different ingredients and methods. Fikiru et al. (2017) found that blends of maize, roasted peas, and malted barley contained 5.0–6.5% moisture, 13–18.5% protein, 3.1–4.1% fat, 1.5–2.5% ash, and 68.9–74.1% carbohydrates—well within recommendations. Mbaeyi-Nwaoha and Obetta (2016) reported similar blends with moisture content of 3.39–4.78%, protein ranging from 14.59–24.27%, fat between 1.21–4.85%, ash 2.51–4.46%, fibre 4.76–11.51%, and carbohydrates 54.87–71.17%. However, the fibre content may be excessive for infants, as high fibre can limit nutrient absorption.

Ikese et al. (2016), studied a wheat-groundnut blend with 8.56% moisture, 1.889% ash, 18.45% protein, 31.22% fat, 2.49% fibre, and 37.40% carbohydrates. Lohia et al. (2015) formulated a complementary food from malted cereals and lentils with 4.3% moisture, 1.2% ash, 1.5% fibre, 11.5% protein, 11.7% fat, and 71.2% carbohydrates. Malting enhanced the nutritional value of this food mix, making it suitable for infant nutrition. Shiriki et al. (2015) evaluated maize, soybean, and peanut blends fortified with *Moringa oleifera* leaf powder. The blend contained 7.06–7.51% moisture, 16.04–17.59% protein, 20.80–23.48% fat, 2.25–4.42% fibre, 1.40–2.50% ash, and 47.63–49.32% carbohydrates. Onoja et al. (2014) reported complementary food from sorghum, soybeans, and plantain flour with high moisture (46.36–50.41%), 11.17–14.21% protein, 5.09–7.13% fat, 3.30–3.48% ash, and 30.10–32.87% carbohydrates, suggesting a shorter shelf life.

Ojinnaka et al. (2013) developed a soybean and ginger-modified cocoyam blend with low fibre (0.81–1.11%), fat (1.22–1.93%), and high carbohydrate (78.55–80.87%), indicating energy suitability for infants. Nandutu and Howell (2009) analyzed sweet potato-based blends with 8.0% moisture, 66.0% carbohydrate, 20.4% protein, 2.0% fat, and 3.2% ash—nutritionally adequate for growth. Das et al. (2019) reported blends with 3.70–5.15% moisture, 13.31–35.6% protein, 15.6–38.1% fat, 9.07–10.8% fibre, and 473.9–598.5 kcal energy from various grains, nuts, and legumes.

Functional Properties of Complementary Foods

Functional properties influence how nutrients behave during food processing, storage, and preparation, affecting overall quality and consumer acceptance (Akubor et al., 2013). These properties determine the suitability of flour for various food applications. Ahmed et al. (2010) noted that several factors—such as sweet potato variety, processing methods (e.g., parboiling, blanching, drying), pre-treatment, and drying temperature—impact the final quality of sweet potato flour. Key functional properties include water and oil absorption capacities, bulk density, foaming ability and stability, swelling capacity, water solubility index, and emulsifying ability (Olaitan, Eke, & Uja, 2014). These characteristics are especially important in protein-rich foods as they influence processing efficiency and final product formulation.

Bulk Density

Bulk density is a key characteristic in food processing, as it influences the packaging and transportation efficiency of food products. According to Olaitan, Eke, and Uja (2014), bulk density also helps determine the weight of flour. Okorie et al. (2011) explain that the bulk density of a food product is affected by the particle size of its ingredients—finer particles tend to yield lower bulk density valu `es. A low bulk density is particularly beneficial because it allows more of the product to be packed into a given volume. Mburu et al. (2011) point out that this trait is especially advantageous in infant food formulation, where a high nutrient content is required in small portions. Akubor et al. (2013) support this, stating that low bulk density is ideal for complementary foods, as it facilitates easier digestion for infants without compromising nutrient content.

Several studies have reported varying bulk density values in complementary foods. Laryea (2016), for instance, found low bulk density values (0.787 to 0.827) in a blend of orange-fleshed sweet potato, millet flour, and soybean flour, indicating a fine particle texture. Lohia and Udipi (2015) recorded values of 0.68 in a malted mix and 0.73 in a fermented mix, both developed from cereals and pulses. Ghasemzadeh and Ghavidel (2011) reported bulk densities ranging from 59.4 to 62.5 for cereal and legume-based complementary foods. Mbaeyi-Nwaoha et al. (2016) observed a range of 0.54 to 0.65 in formulations made from millet, pigeon pea, and seedless breadfruit leaf powder, suggesting they can be compactly packed. Similarly, Onoja et al. (2014) recorded even lower values (0.42 to 0.46) in complementary food made from fermented sorghum, soybean, and plantain.

Swelling power, which reflects a granule's capacity to absorb water during heating, is another functional property of interest. As noted by Onoja et al. (2014), this parameter influences the food's texture and thickness. Ayo-Omogie and Ogunsakin (2013) explain that swelling affects the hydrodynamic behavior of proteins, leading to changes in body and viscosity. Afam-Anene and Ahiarakwem (2014) note that lower swelling capacity is preferable in infant foods, as it supports easier digestion. Laryea (2016) documented swelling power between 6.652 and 7.734, while Okorie et al. (2011) emphasized that lower values aid digestibility in infants. Ikese et al. (2016) observed a swelling index of 23.08 to 24.10 in wheat and groundnut-based complementary foods. Ojinnaka et al. (2013), working with porridges made from soybean flour and ginger-modified cocoyam starch, found swelling powers between 2.56±0.05 and 3.03±0.04.

Water Absorption Capacity

Water Absorption Capacity (WAC) refers to the ability of flour to take in water and expand, which enhances the texture and consistency of food. It reflects the amount of water retained within the protein matrix, indicating the functional strength of the proteins for use in thickening agents and food formulations (Mburu et al., 2011). This property is valued in food applications because it contributes to improved yield, better consistency, and adds structure to the final product (Mburu et al., 2011). Mburu et al. (2011) also emphasize that WAC is a crucial attribute of flour, as it directly affects other functional traits such as viscosity and gelation. These characteristics provide insight into how complementary foods will behave when reconstituted with hot or cold water.

Various studies have reported differing WAC values in complementary food formulations. Ikese et al. (2016) recorded a water absorption capacity of 7.10 in a wheat and groundnut flour blend. Laryea (2016) noted WAC values ranging from 152.5% to 216.7% in sweet potato-based flour. Ghasemzadeh and Ghavidel (2011) developed complementary foods from a combination of cereals and legumes, with WAC values between 465% and 530%. In contrast, Lohia and Udipi (2015) reported lower WAC values of 0.33 and 0.35 for their malted and fermented food mixes, respectively. Onoja et al. (2014) observed a WAC range of 50 to 74.34 in a complementary food made from fermented sorghum, soybean, and plantain flour.

Solubility

Solubility serves as an indicator of protein functionality, including properties like denaturation and potential uses (Adepeju et al., 2014). The solubility of starch varies depending on the type and origin of the crop. In some cases, a food's ability to retain water is linked to its protein content (Adepeju et al., 2014). Water molecules interact with the exposed hydroxyl groups, leading to swelling of the starch granules, which in turn increases starch solubility. According to Adepeju et al. (2014), solubility values in breadfruit-based complementary foods were relatively low, ranging from 3.27% to 4.9%. In contrast, Laryea (2016) reported a solubility index ranging from 17.78% to 20.32%. In Ghana, cereal-based crops are the primary ingredients used in complementary food production (Amagloh et al., 2012).

However, Adepeju et al. (2014) highlighted that complementary foods can also be developed from root and tuber crops like sweet potatoes, due to their high energy content. Sweet potatoes have been incorporated into complementary food formulations both domestically and in industrial settings. For instance, Laryea (2016) developed a complementary food using 65% cereal (maize or sorghum), 30% legume (soybean or cowpea), and 5% sweet potato. The raw components were subjected to processing techniques such as malting, fermentation, drying, and milling to obtain fine flours.

Empirical review

Nkesiga, Anyango, and Ngoda (2022) investigated the nutritional and sensory qualities of extruded Ready-To- Eat baby foods from orange-fleshed sweet potato enriched with amaranth seeds, and soybean flour. This study was carried out to investigate the effect of extrusion cooking and blend proportions on the nutritional qualities of extruded ready-to-eat baby foods. A Completely Randomized Design (CRD) in a Factorial Experimental Design with two variables (blend proportions at 5 levels and extrusion cooking temperature at two levels) was used in the study. Different blends of orange- fleshed sweet potato, amaranth seeds, and soybean flour were used to formulate foods and analyzed for proximate, minerals, vitamin A content, anti-nutrient content, physical properties, and sensory qualities. Extrusion cooking was conducted at a temperature of 90oC, screw speed of 400 rpm, and feed moisture content of 35%.

The results reveal that extruded ready-to-eat baby foods had a high protein content of 15.72%, total minerals (5.39%), carbohydrate content (80.58%), crude fibre content (5.04%), fat content (6.05%), energy value (380.84 kcal/100g), energy-to-protein ratio (128.67 kcal/g of protein) and vitamin A content (1044.70 REA µg/100g). The micronutrients of extruded baby foods resulted in high iron content of 3.10 mg/100g, zinc content (0.64 mg/100g), manganese content (0.90 mg/100g), copper content (0.97 mg/100g), magnesium content (81.70 mg/100g), calcium content (61.22 mg/100g), potassium content (68.18 mg/100g) and sodium content (41.44 mg/100g). The produced ready-to-eat baby foods showed a reduction in anti- nutrients as well as acceptable levels of phytate content which ranged from 0.47-1.79 mg/100g, oxalate content (0.16 – 0.50 mg/100g) and saponin content (0.20 – 0.48 mg/100g). All produced foods were highly accepted through sensory evaluation. These important findings confirm that extrusion cooking is useful in the production of nutrient-dense baby foods.

Adepeju et al., (2024), investigated Nutrient rich complementary food formulation using locally sourced compositions. The study formulated complementary foods using locally abundant and affordable food raw materials. Fermented maize, sorghum, roasted soybeans, crayfish, and date palm fruit were processed into flours separately; and the flours were blended in varying proportion to obtain six formulated complementary diets (A-F). A commercial baby food (maize and soybean-based) served as the control. The proximate composition, functional analysis, vitamin and mineral analysis were

determined on the blends. Sensory analysis of the reconstituted complementary diets was determined using standard procedure.

The results showed that proximate content varied for moisture (2.7% to 12.07%), crude protein (12.71% to 19.34%), fat (1.88% to 9.00%), ash (2.30% to 4.32%), crude fiber (3.08% to 7.00%), and carbohydrate (59.63% to 72.25%). Vitamin and mineral content ranged from Vitamin C (14.13 mg/100g to 74.14 mg/100g), sodium (30.50- 180.00mg/100g), potassium (195.00-570.00 mg/100g), calcium (156.50-500.00 mg/100g), iron (2.16-10.00 mg/100g), zinc (1.55 mg/100g to 6.00 mg/100g). Functional properties included water absorption capacity (111.33 g/ml to 377.00 g/ml), oil absorption capacity (100.43 g/ml to 213.03 g/ml), bulk density (1.66 g/cm^3 to 2.27 g/cm^3), and foaming capacity (3.19% to 6.95%). Sensory evaluation result showed that sample C (30% maize, 30% sorghum, 20% soybean, 10% crayfish and 10% date palm fruit) had the most preferred attributes in term of taste, color, aroma, consistency, texture and overall acceptability when compared with the control diet. The developed complementary food formulation could help to alleviate protein-energy malnutrition among infants in developing countries.

CHAPTER THREE

RESEARCH METHODS

Introduction

The research methodology used in this study is described in this chapter. The research philosophy, research approach, research design, research population, sample and sampling procedure, instruments for data collection and their validity and reliability, and data collection procedures are all discussed in this chapter. Procedures for data analysis as well as ethical considerations are also included in this chapter.

Research Paradigm

The researcher adopts a positivist paradigm for this study. Positivism involves using an observable social reality to generate generalizations that resemble laws and is related to the philosophical position of the natural scientist. The positivists emphasize an entirely scientific empiricist approach that aims to provide facts and data that are free from bias and human interpretation. It is worth mentioning that extreme positivism views organizations and other social entities as real in the same way that physical objects and natural phenomena are real. A positivist researcher uses existing theory to develop hypotheses and assertions. These hypotheses would be tested and confirmed, in whole or part, or refuted, leading to the further development of theory, which may be tested by further research. The positivist philosophy is associated with quantitative methods of conducting research (Creswell & Clark, 2017). As such, the quantitative approach will be used because the researcher seeks factual data. Also, the approach allows an objective analysis of the data, which is devoid of the researcher's values and judgment.

Research Design

The experimental research design was used to conduct the study. The researcher is to see the cause and effect. According to Jankowski and Flannelly (2020), altering or manipulating variables can lead to changes in the independent variable. In this study, to assess the effects of varying amounts of sweet potatoes, soybeans, and shrimp on both the nutritional content and sensory qualities (such as taste, appearance, aroma, and texture), the formulation was deliberately adjusted. This design was considered suitable for the study as it allowed the researcher to develop an infant food product while analyzing its chemical composition and nutritional value.

A key benefit of this design is its ability to strongly support conclusions about cause-and-effect relationships. The experimental method gives the researcher significant control over the study. In an experimental setup, the goal is to answer a specific question clearly. To achieve this, it is essential to control or eliminate the influence of unrelated variables. Additionally, this method allows for the precise manipulation of one or more variables under clearly defined experimental conditions. As a result, the outcomes can be interpreted with confidence, since participants' responses are expected to reflect primarily the variables that were intentionally introduced by the researcher.

Study Area

The research was carried out in Pokuase, a town situated within the Ga North Municipal Assembly (GNMA), one of the Municipalities in the Greater

Accra Region. Ofankor, Amormorle, and Pokuase are some of the major towns found in the municipality. The municipality has Ofankor as its capital town. The municipality lies between latitude 5o37'0 North, 5o 42'14 North, and longitude 0o 19'31 West and 0o 13'42 West respectively, and occupies a land area of 636.28sq km. It shares boundaries with Ga West Municipal to the north, Ga Central and Ablekuma North Municipalities to the west, Accra Metropolitan to the south and Ga East Municipality to the east. The area is predominantly populated by children, with a relatively small percentage of elderly individuals aged sixty and above (Amankwaa, 2020). The population of the municipality according to the 2021 population and housing census stands at 235,292 with 116,481 males and 118,811 females (Assembly, 2022).

Pokuase, one of the major towns in GNMA, was the preferred study location because the researcher's familiarity with the region's landscape facilitated the collection of data within the limited stipulated time for the submission of the final work. Also, empirical evidence shows that breastfeeding and timely complementary feeding practices are suboptimal in the Greater Accra Region of which Pokuase is no exception. This made Pokuase to be the preferred study location.

Population

The group that a researcher aims to gather information about and make conclusions from is referred to as the population. This population consists of individuals who share one or more traits relevant to the research. In this particular study, the target population will include all infants residing in Pokuase. In this study, the accessible population comprised infants aged six (6) to twenty-four (24) months living in Pokuase, located within the Ga North

Municipal Assembly (GSS, 2021). This population was targeted because reports have shown that there is a substantial percentage of children 6–24 months in Ghana who were both anaemic and stunted at the same time. Therefore, the study sought to develop complementary infant food that is nutritious and cost-effective. It would help to solve the health problems identified among this population. In this study, the accessible population comprised 65 infants in Pokuase who routinely visited post-natal care.

Sampling Procedures

The researcher employed a purposive sampling method and, with the assistance of the infants' mothers, selected 65 children between the ages of six and twenty-four months for the study. The researcher used 65 infants with their mothers from Pokuase municipal hospital, as a sample size. The sample size was justified based on the recommendations of Etikan (2017), who suggested that a hedonic scaling test requires a sample of between 40 and at least 100 targeted participants. Sampling was conducted at Pokuase Municipal Hospital, involving infants whose mothers brought them for post-natal care. The researcher obtained an attendance list of all babies who visited the hospital and used random sampling to select 65 infants. From the pool of 100 babies who regularly attended post-natal care, those aged between six (6) and twenty-four (24) months were chosen for the study.

Data Collection Instruments

The nutritional composition, consumer acceptability, and shelf-life of the product samples were determined using standard methods. However, to sensorily evaluate the formulated infant food in terms of its appearance, taste, texture, and aroma, an observation checklist was used for data collection. A sensory evaluation questionnaire was adopted and used. The questionnaire was adapted to suit the current study's context. In addition, trained panels were used to evaluate the new product for acceptability. Data for this study was gathered using an adapted instrument designed to obtain information regarding the acceptability or lack thereof of the formulated infant food. The respondents were asked to rate the extent to which they liked or disliked the six product samples based on their appearance, texture, taste, aroma, and overall acceptability. The ratings were on a five-point like scale, ranging from (1) very dislike to (5) very like.

Data Collection Procedure

An introductory letter issued by the Head of Department., Department of Vocational and Technical Education, UCC, with a consent letter from the principal investigator and proposal for the study were submitted to the Institutional Review Board (IRB), UCC and the Ghana Health Service Ethics Review Committee (GHSRC) Accra for permission to collect data. The purpose of the letter was to seek permission to solicit cooperation and create rapport between the researcher and the mothers who served as respondents for the study. The questionnaire was be administered personally. This offered an opportunity for the researcher to brief respondents on understanding exactly what the items meant to obtain the right responses.

For respondents who were unable to read or write, the researcher explained the items in the respondents' dialect. Where the service of an interpreter was needed to be engaged, the researcher relied on such persons but with the respondents' consent. Alternatively, the respondents were made to introduce persons they felt more comfortable with to explain the items in a language they could understand.

Ethical Considerations

The instrument and proposal were submitted to the University of Cape Coast Institutional Review Board (UCCIRB) to check validity and reliability and also to ensure that the respondents were not put into any risky or uncomfortable situations during data collection. Options were made for suggestions to be accepted or declined to share specific details. In other words, IRB ensured that for respondents, participation in the research was entirely voluntary. Moreover, the researcher protected the confidentiality and integrity of the research by keeping the data well and using it for research only.

Materials and Methods

Sources of Raw Materials

The orange-fleshed sweet potatoes were purchased from the Pokuase market. The other ingredients; soybeans and shrimp were bought from the same market in Pokuase.

Preparation of Soybean Flour

The soybean flour was prepared following a method reported by Raigar and Mishra (2021). Five kilograms (5 kg) of soya beans were sorted and broken beans, stones, pest-infected ones, and other dirt were removed while the good ones were soaked for 18 hours in 15 Litres of potable water to give a bean-water ratio of 1:3. The soaked beans were drained, rinsed with potable water and dehulled. Afterward, the dehulled beans were sun-dried for 12 hrs, roasted for 3 minutes, and using an attrition mill, the dried soybean was milled into powder and sieved at (30µm) sieve to obtain finer flour, and later kept in zip-lock bags for analysis.

Preparation of Orange Flesh Sweet Potato flour.

The tubers of OFSP varieties were processed into flour using the method reported by Aparecida Pereira et al. (2019) with some modifications. Exactly, two hundred kilograms (200 kg) of the tubers were sorted, weighed, washed, peeled, and divided into thin slices using a sharp stainless knife; the thin-sliced tubers were dried in an oven at 60°C for 48 hr. Then, the dried chips were pulverized and sieved through a 250 µm mesh sifter to finer flour and stored at 4°C in zip-lock bags before use.

Preparation of Shrimp Flour

The Whiteleg shrimp (Litopenaeus vannamei) was processed into flour by the method reported by Rizkiyanda et al. (2024) with some modifications. Exactly, 5kg of the shrimp shells were washed with running water, the shrimp shells were cut to 1 cm, and the shrimp shells were boiled in boiling water for 12 hours (the first 4 hours the water was changed every 30 minutes, the rest every 1 hour), the shrimp shells were removed and drained, the shrimp shells were dried in an oven at 121°C for 60 minutes, the shrimp shells were then ground with a blender, then the shrimp shells were sieved using a 100 µm mesh sieve and was stored at 4°C in zip-lock bags before use.

Experimental Design for Mixing Orange-Fleshed Sweet Potatoes-Soybean Flour-Shrimp Flour

A simple centroid mixture design for two components in Minitab was used for composite flour formulation as depicted in Table 1. This design was chosen based on its robustness for optimization studies involving food prepared from many ingredients. The effects of different proportions of orange-fleshed potatoes. Sweet potato flour (OFSPF) from 10 % to 20 % and soybean flour (SBF) from 70 % to 80 % were selected for the study. These values are based on a similar ready-to-use porridge enrichment protocol with buckwheat flour (Hussain & Kaul, 2019). Also, 10% shrimp flour was added to all the formulations and 100% orange-fleshed sweet potato flour was used as control. Other ingredients like tomatoes and onion powder were added at 5% in all the samples.

Table 1: Centroid Design for Orange-Fleshed Sweet Potato-Soybean-Shrimp Composite Flour

Coded	OFSPF (%)	SBF (%)	SPF (%)	TMF (%)	ONF (%)
X_{00}	100	00.00	10	5	5
X_{80}	10	80	10	5	5
X_{78}	12	78	10	5	5
X_{75}	15	75	10	5	5
X_{72}	18	72	10	5	5
X_{70}	20	70	10	5	5

Source: Author's construct, 2024.

Formulations of Infant Food

The formulation of the infant food was carried out using a protocol reported by Aparecida Pereira et al. (2019) with some modifications. Six different formulations were obtained after weighing and mixing the varied percentages of the flours. To improve the flavour, and other essential minerals, tomatoes and onion powder were added.

Determination of Functional Properties

Determination of bulk density

As reported by Idowu et al. (2021), the bulk density of each sample was determined when 10 g flour was weighed into a 50-calibrated measuring cylinder. The samples were packed gently by tapping the cylinder on the benchtop ten times from a height of 5cm. The volume of the sample occupied in the measuring cylinder was recorded and the bulk density was calculated as follows: $P_b = \frac{W_t}{V_t}$

Where P_b is bulk density (g/ml), Wt is the weight of the tapped sample (g), and Vt is the volume of the tapped sample (ml).

Water and Oil Absorption Capacity (WAC and OAC)

A method reported by Idowu et al. (2021), was adopted to estimate the water/oil absorption capacity with slight modification. In this method, 10g of each sample was added to about 10 ml of distilled water or oil in a glass beaker and stirred. The soaked samples were drained through a filter paper for half an hour. The water and oil absorption capacity were then computed using the expression as the weight of soaked flour per weight of the dried flour:

$$\% \text{ WAC and OAC} = \frac{W_s}{W_d}$$

Where, WAC, and OAC, are the water and oil absorption capacity, Ws is the weight of the soaked flour sample, and W_d is the weight of the dried flour sample.

Determination of swelling capacity

As reported by Idowu et al. (2021), 80mL of distilled water was added to 20 g of weighed samples into a calibrated, cleaned measuring cylinder, and air bubbles were eliminated by mixing carefully and quickly. The final volume was then recorded after the sample was allowed to settle for 3 hr. The swelling ability was then computed using the equation below:

$$S_c = \frac{V_f}{V_i}$$

Where S_c is the swelling capacity, V_f is the final volume (ml), and V_i is the initial volume (ml).

Solubility Index

The water solubility index was determined using the approach given by Idowu et al. (2021). Exactly, 1g of flour was dissolved in 10 mL of distilled water in a graduated centrifuged tube. The mixture was heated at 85°C in a Bain-marie (5 L) water bath for 30 min with gentle mixing. It was then cooled to room temperature, and centrifuged with Gallenkamp bench top angle head centrifuge at 2200 rpm for 15 min. The solubility was determined by evaporating the supernatant in a gallenkamp/Sanyo OMT 225 laboratory oven at 105°C. The sediment paste was weighed and the water solubility index was calculated as

$$\% \text{ water solubility index} = \frac{\text{weight of soluble}}{\text{weight of sample}} \times 100$$

Determination of Nutritional composition

Moisture Content

The moisture content was determined by the hot air oven method as reported by Ezeocha and Onwuneme (2016). An empty crucible was weighed and 2g of the sample was transferred into the crucible. This was taken into the hot air oven and dried for 24 hours at 100°C. The crucible and its contents were cooled in the desiccator and their weights were taken. The loss in weight was regarded as moisture content and expressed as;

% moisture = $\frac{mass\ of the\ water}{mass\ of sample}$ x 100

Ash Content

Ash content was determined using the method reported by Laurie et al. (2018). About 5 g of each sample was weighed into crucibles in duplicate, and then the sample was incinerated in a muffle furnace at 550°C until light grey ash was observed and a constant weight obtained. The sample was cooled in the desiccator and weighed to obtain ash content.

Ash (%) = $\frac{Weight\ of\ the\ residue}{Weightof\ the\ original\ sample} x\ 100$

Crude Fibre

The crude fibre was determined using the method reported by Laurie et al., (2018). About 5 g of each sample was weighed into a 500 ml Erlenmeyer flask and 100 mL of TCA digestion reagent was added. It was then brought to boiling and refluxed for exactly 40 minutes counting from the start of boiling. The flask was removed from the heater, cooled a little, and samples filtered through a 15.0 cm number 4 Whatman paper. The residue was washed with hot water stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight at 105°C. After drying, it was put into a desiccator and weighed as W_1. It was then burnt in a muffle furnace at 500°C for 6 hours, allowed to cool, and reweighed as W_2.

% crude fibre = $\frac{W_1 - W_2}{W_0}$ X 100

W_1=weight of crucible+fiber+ash, W_2=weight of crucible+ash, W_0=Dry weight of food sample.

Fat Content

The Soxhlet extraction method reported by Laurie et al. (2018), was used to determine the fat content of the samples. About 2g of the sample was weighed and the weight of the flat bottom flask was taken with the extractor mounted on it. The thimble was held halfway into the extractor and the weighted sample. Extraction was carried out using (boiling point 40-60°C). The thimble was plugged with cotton wool. After the extraction, the solvent was removed by evaporation on a water bath and the remaining part in the flask was dried at 80°C for 30 minutes in the air oven to dry the fat and cooled in a desiccator. The flask was reweighed and the percentage of fat was calculated as;

$$(\%)\ \text{Fat} = \frac{Weightloss}{Weightofsample} x\ 100$$

Protein Content

The micro Kjedal method as reported by Malavi et al. (2022), was used to determine crude protein. About 2 g of the sample was put into the digestion flask. Ten grams of copper sulphate and sodium sulphate (catalyst) in the ratio of 5:1 respectively and 25 mL of concentrated sulphuric acid were also added to the digestion flask. The flask was placed into the digestion block in the fume cupboard and heated until frothing ceased giving clear and light blue-green coloration. The mixture was then allowed to cool and diluted with distilled water until it reached 250 mL volumetric flask. The distillation apparatus was connected, and 10 mL of the mixture was poured into the receiver of the distillation apparatus also 10 mL of 40% sodium hydroxide was added. The released ammonia by boric acid was then treated with 0.02 m of hydrochloric acid until the green colour changed to purple. The percentage of nitrogen in the sample was calculated using the formula below:

$$\text{Nitrogen (\%)} = \frac{(Titre - Blank) x 14.008\, x Normality}{Weight of sample} x\ 100\%$$

% crude protein = % Nitrogen x 6.25

Determination of Carbohydrate Content

The carbohydrate content was calculated by difference according to Kidane et al. (2013).

Determination of β-Carotene

βeta-carotene of the OFSP-Soy beverage was determined by adapting a procedure described by Sadaf et al. (2013). Briefly, 10mL of each sample was transferred into a volumetric flask. 10 mL of absolute acetone was added and left for 20 mins with periodic shaking. The extraction with ethanol was repeated thrice ensuring that most of the pigment was removed from the samples, and filtered using 0.45-μm filter paper. Exactly 15 mL of petroleum ether (80–100℃) was added to the filtrate, shaken gently, and left to stand for 20 min to obtain a two-layered solution. The top layer with the β-carotene was pipetted, and absorbance was read using a spectrophotometer (UNICO 7200, Shanghai, China) at a wavelength of 450 nm against a blank of petroleum ether. The β-carotene was calculated using;

$$\text{Total carotenoids } (\mu g/ml) = \frac{ABS \times V\ (ml) \times 10{,}000}{2592 * W\ (ml)}$$

where; ABS is the absorbance, V (mL) is the volume of solvent used for the extraction, W (ml) is the weight/volume of the sample initially taken, and 2,592 is the extinction coefficient of β-carotene in petroleum ether.

Determination of Vitamin C

Vitamin C of the infant food was determined by weighing 2 g of the flour into 50 mL capacity extraction flasks. Exactly 20 mL of 4 % oxalic acid was added, homogenized, and filtered using a Whatman filter paper (12 mm pore size). Then, 10 mL of the filtrate was pipetted into a 100 mL flat bottom flask, and bromine was added in drops. The solution was made to the volume. Then, 1.0 mL of the brominated sample extract was pipetted into a test tube and a drop of thiourea was added. The solution was then made to the 3 mL mark using distilled water. Then, 1.0 mL of 2.4 Dinitrophenylhydrazine was added to each test tube. The content was mixed and incubated at 37 °C for 3 h. The osazone derivative formed was dissolved in 5 mL of 80 % sulphuric acid and the solution was allowed to cool. The absorbance of each solution was determined with the help of a UV-VIS spectrophotometer at 540 nm. A standard calibration curve was made by preparing various concentrations (0, 48, 96, 144, and 194 ug/ mL) of ascorbic acid and similarly treated as previously explained. The quantity of ascorbic acid was estimated by using the expression.

$$\text{Ascorbic acid (mg/100g)} = \frac{C x V}{WT} x \; D x 100$$

Where C is the concentration (mg / 100 g), v is the volume (mL), Wt. (g) sample weight, and D the dilution factor

Determination of Minerals Content

The minerals Iron (Fe), Zinc (Zn), Phosphorus (P), and Potassium (k) were determined using a method called atomic absorption spectrometry. The atoms of an element were vaporized and atomized in the flame. The atoms then absorb the light at a characteristic wavelength. The absorbed energy was measured using a photo-detector read-out system. A digested sample was analyzed for mineral contents by Atomic Absorption Spectrophotometer. The determination of phosphorus (P) was done using the ascorbic acid method.

Sensory Analyses

To determine the acceptability of orange-fleshed sweet potato infant food enriched with soybean flour (SBF), the methods reported by Dankwa et al. (2017) and Stone et al. (2012) were used. The consumer acceptance of the infant food was assessed in Pokuase Hospital Post-Natal Centre, Ga North in Greater Accra using 65 babies of 6-24months with their mothers. Before the sensory exercise, panelists were oriented about the importance of undergoing the experiment and trained to assess the product during the evaluation. They were instructed to rinse their mouth after each taste, avoid interaction with other panelists during the exercise, and withdraw from the exercise if they were allergic to ingredients or were on medication. The panelists evaluated the infant food samples on a 5-point Hedonic scale by selecting or marking one of the five alternatives (5 = very like, 4 = moderately like, 3 = neither like nor like moderately, 2 = dislike, 1 = very dislike). The samples were evaluated for; appearance, texture, taste, aroma, and overall acceptability. The infant food was presented in six food warmer flask coded individually, served in plain disposable plastic cups with spoons. The sensory evaluation was carried out in an airy, spacious room under white colour lighting. Bottle water was provided for the panelists to rinse their mouths between samples to prevent the carry-over effect of taste.

Statistical Analyses

To determine the effects of Baobab flour substitution on the response parameters, Minitab software was used to analyze the data for the mean and variance at a significance level of 95 %. Graphs were plotted using Excel software. Tukey comparison test was conducted to determine the significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The study explored using soybean, orange-fleshed sweet potatoes, and shrimp composite flour to develop infant food using composite flour. However, the flour's functional properties such as bulk density, swelling capacity, water/oil absorption capacity, and solubility index were investigated. Infant food was developed from the composite flour and analysis of nutritional composition, mineral content, and physicochemical qualities like vitamins C, and Beta carotene were investigated. The study explored the effects of soybean flour incorporation into orange-fleshed sweet potato infant food and fortified with shrimp flour at 10% to all the samples.

Effects of Soybean Flour Enrichment on Functional Properties of Orange-Fleshed Sweet Potatoes-Soybean Composite Flour

The functional properties of food material impact its interaction with other components and end applications (Ocheme et al., 2018). Flour with better functional properties increases the possibility of being incorporated into highly yielding-foods (Suleman et al., 2023). Bulk density remains the quality criterion in the functional attributes of composite flour. The bulk density of flour is affected by the structural arrangement of carbohydrates and other polymers. The results indicate that fortifying orange-fleshed sweet potato flour (OFSPF) with soybean flour led to a general decrease in the bulk density of the composite flour. It was observed that the control sample (100% OFSPF) has the highest bulk density (0.76g/cm^3), which decreases to a range of 0.69g/cm^3 to 0.63g/cm^3 at a decrease in soybean flour replacement from 80%

to 70% respectively. From the results, decreasing the soybean flour replacement by 2%, a difference between 80% and 78% does not have significant ($p<0.05$) effects decrease in the composite flour bulk density. Also, a further decrease in the soybean replacement from 75% to 72% led to a 0.1g/cm^3 decrease in the bulk density hence not significant. The reduction in bulk density may be caused by soybean flour. The high amount of soybean flour may increase the protein profile and affect the carbohydrate structure and particle size, reducing the bulk density of the composite flour.

Also, the inclusion of soybean flour caused an increase in the protein hydrophobic character based on the exposure of the non-polar amino acids, reducing the water absorption and respected bulk density. The results of this study were similar to that of Alamu et al. (2021) who recorded a decrease in bulk density when soybean flour was added. Similarly, Verem et al. (2021) reported that replacing wheat flour with 20% soybean flour increases the bulk density due to high protein content increasing the carbohydrate structure. Flour with a low bulk density would be convenient for packing, and transportation. Notwithstanding, low bulk density indicates less moisture content and hence low microbial growth. The results suggest that the composite flour would have a high shelf-life and storage stability.

Swelling Capacity

The swelling capacity of flour depends on several factors including the variety, particle size, and the flour processing method (Meherunnahar et al., 2018). Swelling capacity is the function of the volume increase of the product when interacting with water (Twinomuhwezi et al., 2020). Swelling capacity is one of the functional quality indicators of flour functionality which helps to predict its water requirement. From the results, it was observed that the swelling capacity of the 100% OFSPF was 15.16, being the lowest among the samples. Fortifying Infant food made from orange-fleshed sweet potato with a maximum addition of soybean flour has led to a general increase in the swelling capacity of the composite flour. The swelling capacity increased from (17.17 to 17.89) at a decrease in soybean flour from 80% to 70% respectively.

The results show that the higher the soybean flour, the lower the swelling capacity and the lower the soybean flour, the higher the swelling capacity. Also, a lower swelling capacity was observed at 78% of soybean infant food flour. The results suggest that increasing the soybean flour replacement by 2% significantly decreases the swelling capacity. However, a further decrease in soybean flour by 3% (D-E) increases the swelling capacity by 0.29. Moreover, a decrease in soybean flour by 2% (E-F) increases the swelling capacity by 0.14 (17.89-17.75). Generally, decreasing the soybean flour inclusion in the orange-fleshed sweet potato infant composite flour increases the swelling capacity. The addition of soybean flour may influence the protein content resulting in variations of the swelling capacity. The results of this research concord with the findings reported by Godswil (2019) that the swelling capacity of different grain flour fortified with soybean flour was higher than wheat flour.

Furthermore, Erben and Osella (2017) confirmed that protein concentrate with high soybean inclusion recorded a higher swelling capacity. The results suggest that soybean flour would reduce the swelling capacity hence, less bulk nature with convenient packing ability. Soybean flour contains higher protein content than orange-fleshed sweet potato. Therefore, higher swelling capacity relates to the water association thus, increasing the soybean flour decreases water absorption, and less microbial growth, influencing the storage stability and shelf-life of the orange-fleshed sweet potato-soybean composite flour and the infant food made thereof.

Table 2: Effect of Soybean Flour Enrichment on the Functional Properties of Orange-Fleshed Sweet Potato Composite Flour

CODE	SBF: OFSPF: SPF (%)	Bulk Density	Swelling Capacity	%WAC	%OAC	Solubility index
A	00:100:10	0.76 ± 0.00^{a}	15.16 ± 0.04^{e}	185.63 ± 0.22^{e}	196.84 ± 0.25^{e}	16.20 ± 0.08^{d}
B	80:10:10	0.69 ± 0.01^{b}	17.17 ± 0.05^{b}	229.63 ± 0.35^{b}	217.33 ± 2.39^{b}	17.25 ± 0.06^{b}
C	78:12:10	0.68 ± 0.01^{bc}	16.83 ± 0.07^{c}	214.85 ± 0.10^{d}	228.81 ± 0.46^{c}	16.31 ± 0.10^{e}
D	75:15:10	0.66 ± 0.00^{cd}	17.46 ± 0.06^{a}	218.50 ± 0.33^{c}	231.57 ± 0.47^{c}	16.74 ± 0.25^{c}
E	72:18:10	0.65 ± 0.00^{d}	17.75 ± 0.11^{d}	224.53 ± 0.16^{d}	244.03 ± 0.82^{d}	16.53 ± 0.26^{cd}
F	70:20:10	0.63 ± 0.00^{e}	17.89 ± 0.09^{a}	244.07 ± 0.13^{a}	255.49 ± 0.73^{a}	18.15 ± 0.15^{a}

Source: Author's construct, 2024.

Mean values in a column that do not share the same letter are significant ($p<0.05$) different

Water Absorption Capacity (WAC)

Water absorption capacity (WAC) measures the starch's ability to hold water after swelling water depending on the presence of hydrophilic groups binding the water molecules. Water absorption capacity represents the ability of the food products to associate with water during conditions when water is limited such as in doughs and pastes (Oppong et al., 2024). After fortifying the already orange-fleshed sweet potato infant food flour, it was observed that the water absorption capacity was enhanced. The %WAC of the control sample was 185.63%, the lowest among the samples. However, there was a significant increase in the %WAC when soybean flour was replaced in higher quantity ($p<0.05$). The %WAC of the composite flour falls from (214.85±0.10% to 244.07±0.13%).

It was noticed that 70% inclusion of soybean flour had the highest %WAC while sample C with 78% of soybean flour had the lowest %WAC. Also, it was noticed that samples C (78%), and E (72%) were not significantly different. The addition of soybean flour may cause an increase and variation in the water absorption capacity of the composite flour. Water absorption capacity depends on the availability of hydrophilic groups that bond to water molecules (Olaoye et al., 2006). Also, Length (2013) reported that proteins are mainly responsible for bulk water uptake and to a lesser extent starch content. Thus, soybean flour may cause an increase in the protein content and the hydrophilic nature of soybean flour protein which is increasing with a concomitant decrease in the starch content.

The results of this research collaborate with the findings reported by Length (2013) including soybean flour in tapioca-soybean composite flour increases the water absorption capacity. The results are similar to the studies reported by Godswil (2019) who stated that substituting soybean flour increases the water absorption capacity of grain composite flour. Water absorption capacity is imperative in food where water will be imbibed without the dissolution of protein, therefore, increasing the viscosity and body thickening (Zaker et al, 2012).The results show that the flour blends would be useful in foods such as bakery products which require hydration to improve handling features.

Oil Absorption Capacity (OAC)

The oil absorption capacity (OAC) is the physical entrapment of oil, indicating which flour protein content bonds to fat during food formulation (Godswil, 2019). The lower oil absorption capacity of flour could be due to low hydrophobic proteins showing superior lipid binding (Odedeji & Adeleke, 2010). From the results, replacing a greater portion of orange-fleshed sweet potato with soybean flour has led to a significant ($p<0.05$) increase in the %OAC of SBF-OFSP composite blends. It was noticed that the %OAC of the 100%OFSP flour was 196.84%, being the lowest among the samples. On the other hand, adding soybean flour increased the %OAC from (247.33± 2.39% when 80% of SBF was added to 255.49±0.73% at 70% inclusion of soybean flour.

There was no clear trend in the flour oil absorption capacity of the OFSP-SB composite blend when a high amount of soybean four was introduced. Decreasing the inclusion of soybeans from 78% to 75% does not significantly ($p<0.05$) increase the %OAC of composite flour (228.81±0.46% to 231.57±0.47%) respectively. However, a further decrease in soybean flour substitution by 2% (sample E-F) significantly increases the %OAC of the composite blend from (244.03±0.82% to 255.49±0.73%) at 72% to 70% levels of soybean flour respectively. The higher composite flour oil absorption capacity compared to the 100% OFSP flour may be caused by the soybean flour inclusion.

The mechanism of oil absorption is related to the binding of fat to the apolar chains of proteins (Odedeji & Adeleke, 2010). Several studies reported that soybean flour is known for its high protein content thus, increasing the inclusion, increases the apolar chain of protein which may increase oil absorption capacity. The results also suggest that soybean flour inclusion influences amino acid composition and surface polarity of hydrophilicity (Chandra & Samsher, 2013). The results collaborate with the findings reported by Chandra and Samsher (2013) that soybean flour had a high apolar chain of protein and increased the oil absorption capacity. Similarly, Oluwamukomi et al. (2011) confirm that increasing the incorporation of soybean flour increases the oil absorption capacity of biscuits. The flavour of food is associated with fat content; thus, this flour would be relevant for improving the flavour and texture when used in food preparation.

Solubility Index

In the food system, solubility refers to the ability of solid, liquid, or gaseous food substances, referred to as solutes, to dissolve in a liquid, gas, or solid solvent. The solubility of a substance is primarily influenced by the chemical and physical characteristics of both the solute and solvent, as well as factors such as pressure, pH, temperature, and the presence of other chemicals in the solution (Awuchi et al., 2019). Flour solubility is the amount of flour that dissolves into a solution, with water as a solvent (Awuchi et al., 2019). Thus, from the results, it was observed that the solubility index of the 100% OFSP flour was 16.20±0.08%, being the lowest among the samples. However, replacing the OFSP with a considerable amount of soybean flour has led to a general increase in the solubility power of the composite blend. It was observed that 80% soybean flour inclusion had (17.25), while 70% inclusion recorded (18.15) of solubility index.

Additionally, decreasing the inclusion of soybean flour from 80% to 78% further decreases the solubility by 0.94, while decreasing from 78% to 75% increases the solubility index by 0.41, indicating that there is no clear trend in soybean flour's impact on the solubility index. Soybean flour has a high amylase content which is water soluble compared to orange-fleshed sweet potato which contains amyl pectin a water-insoluble (Syafutri et al., 2023). Therefore, the increase in the solubility index may be caused by the greater proportion of soybean flour added. To some extent, the flour solubility index is influenced by the particle size of the flour; thus, the smaller the particle, the quicker the solubility index. Therefore, the increase in the solubility index may be caused by adding soybean flour, decreasing the particle size of the composite flour from particulate size to finer particle which elevates the solubility index of the OFSP-SB composite flour. Also, several factors like solute concentration, protein network, and solvent polarity influence the solubility of flour (Iwe et al., 2016). Therefore, the soybean addition of soybean flour may influence solute concentration and increase the protein content and solvent polarity.

The results collaborate with findings reported by Godswil (2019) that the solubility of flour fortified with soybean flour was high. Furthermore, Odedeji and Adeleke (2010) confirmed that fortifying potato flour with soybean flour improves the flour particle size, elevating the solubility index of potatoes-soybean composite flour. However, similar ranges of flour solubility were reported by Roger et al. (2022) confirm an increase in the solubility index of potato-soybean composite flour when a high amount of soybean flour was added to biscuit production. Moreover, the high solubility of the flour shows its digestibility of food which may indicate excellent use for infant formula and food. Moreover, the results may be relevant for improving the utility of local brown rice and soybean flour in the food industry.

Nutritional Composition of Orange-Fleshed Sweet Potato-Soybean Infant Food

Moisture Content

The nutritional composition of the infant orange-fleshed sweet potato food was assessed as depicted in Table 2. The moisture content of the control infant food (100% OFSP) was 9.56±0.23%, the lowest moisture among the samples. However, replacing a higher portion of the orange-fleshed sweet potato infant food with soybean flour resulted in a significant ($p<0.05$) increase in the moisture content. The moisture content of the composite infant food ranges from (9.56±0.09% to 10.39±0.17%) when 80% and 70% of soybean flour was used to replace orange-fleshed sweet potato flour. It was noticed that the lesser the soybean flour, the higher the moisture content. However, there was no clear trend of impact on the moisture content when soybean was added. Also, decreasing the inclusion of soybean flour from 78% to 75% or 72% does not significantly impact the moisture content of the infant food. It was noticed that the sample F (70:20:10) had the highest moisture content among the samples.

Although soybean flour was low, the higher amount of orange-fleshed sweet potato added may cause an increase in the moisture content. The decrease in moisture content at an increase in soybean flour may be attributed to the high protein, ash, fat/oil, and fibre profile in soybean flour compared to orange-fleshed sweet potato. In fact, the lower the moisture content of the flour, the greater its ability to absorb water during kneading, allowing the dough to achieve an optimal consistency (Roger et al., 2022).

The results of this research agree with the findings reported by Olaoye et al. (2006) that increasing the inclusion of soybean flour decreases the moisture content of the wheat-soybean composite flour. Similarly, Godswil (2019)reported a decrease in the moisture profile of wheat-soybean composite blends with increasing soybean flour inclusion. Moreover, low moisture content enhances its storage stability by preventing mould growth and reducing biochemical reactions, which will help increase the shelf life of products made from flour blends.

Ash Content

Ash content indicates the mineral content profile of foods,which provides an indication of the overall amount of mineral content present in the food. The mineral content in the form of ash content, an imperative nutrient improving metabolic activities was determined in the infant food as depicted in Table 3. The ash profile of the control sample (100%OFSP) infant food was (1.85±0.05%), the lowest among the samples. However, decreasing the inclusion of soybean flour has led to a significant decrease in the ash profile of the infant food ($p<0.05$). The ash profile of OFSP-SB composite infant food ranges from (5.16±0.22% to 4.44±0.19%). It was noticed that the ash profile was higher ((5.16±0.22%) at 80% soybean flour inclusion while 70% recorded the lowest ash profile indicating low mineral content. From the results, decreasing the incorporation of soybean flour has a progressive decrease in the ash content of infant food. However, a further decrease in the soybean flour inclusion from 78% to 75% or 72% does not significantly decrease the ash profile of infant food. The addition of soybean flour may cause a higher increase in the ash content of the infant food. Also, it was noticed that decreasing the soybean flour and increasing the OFSPF in the infant food causes a decrease in the ash profile hence, indicating that more OFSPF causes a dilution and reduces the soybean flour ash profile. Soybean seeds have been reported to contain an appreciable amount of minerals and fat (Godswil, 2019), thus contributing to the highest ash content at an increased level. Ash profile is an essential nutrient that helps in the body's metabolic function. Therefore, the results suggest that the OFSP-SBF composite infant food would help reduce malnutrition and its associated problems in developing nations.

Protein Content

The protein content of food is critical as protein contributes to the health function of the body. Infant food with the maximum protein is beneficial for health growth, and development (Kanmani et al., 2021). The replacement of a greater portion of OFSP with soybean flour has led to a significant increase in the protein profile of the infant food. The protein profile of the unenriched soybean flour infant food was 5.99±0.02%. However, the protein profile increases within a range of 33.11±0.13% to 25.25±0.12% when soybean flour was added at 80% to 70% respectively. The results indicate that decreasing the inclusion of soybean flour progressively decreases the protein profile of the infant food. The protein profile decreases from (33.11±0.13% to 29.49±0.13%), at a decrease in soybean flour from 80% to 78%. However, further decreasing soybean flour from 78% to 75% led to a significant decrease in the protein profile of the infant food to 27.49±0.14%. However, no significant ($p<0.05$) decrease in the protein profile was observed when reducing the soybean flour inclusion from 75% to 72%. Also, the lowest protein content was noticed at 70% inclusion of soybean flour. Soybean seeds have been reported to be a good vehicle for protein in the legume crop (Godswil, 2019).

Therefore, an increase in protein profile may be attributed to the high protein in soybean seeds. The results of this research coincided with the findings reported by Oluwamukomi et al. (2011) who stated that increasing the inclusion of soybean flour in biscuits resulted in a higher protein profile comparable to wheat flour biscuits. This increase was expected, as legumes have a higher protein content compared to cereals, leading to a synergistic effect through protein complementation (Godswil, 2019). Further, a similar increase in the protein profile was reported by Olaoye et al. (2006) that bread enriched with soybean flour had the highest profile compared to bread from whole wheat flour. The improvement in the protein content in infant food suggests that orange-fleshed sweet potato and soybean flour would help reduce protein deficiency in the diet of most developing nations.

Table 3: Effect of Soybean Flour Enrichment on Nutritional Composition of Orange-fleshed Sweet Potato Infant Food

CODE	SBF: OFSPF: SPF (%)	% Moisture	% Ash	% Protein	% Oil/Fat	% Fibre	% CHO
A	00:100:0	9.52±0.23[b]	1.85±0.05[d]	5.99±0.02[e]	0.50±0.00[e]	3.86±0.09[d]	78.54±0.20[a]
B	80:10:10	10.39±0.17[a]	5.16±0.22[a]	33.11 ±0.13[a]	14.82±0.11[a]	8.87±0.12[a]	27.65±0.08[f]
C	78:12:10	10.17±0.06[a]	4.89±0.10[ab]	29.49 ±0.13[b]	12.30±0.48[b]	8.45±0.12[ab]	34.70±0.38[d]
D	75:15:10	10.07±0.07[a]	4.84±0.05[abc]	27.49 ±0.14[c]	11.60±0.32[bc]	8.15±0.06[b]	37.85±0.58[c]
E	72:18:10	9.56±0.09[b]	4.56±0.23[bc]	27.47 ±0.30[c]	11.23±0.26[cd]	8.02±0.03[bc]	39.16±0.73[b]
F	70:20:10	8.78±0.20[c]	4.44±0.19[c]	25.25 ±0.12[d]	10.74±0.24[d]	7.56±0.38[c]	43.19±0.65[cd]

Source: Author's construct, 2024.
Mean values in a column that do not share the same letter are significant ($p<0.05$) different

Fat/Oil Content

Fat/oil performs several critical functions as it generates hormones and is an energy source. Also, without lipids, maximum digestion and absorption would not be possible. However, vulnerable people make maximum utilization of fat as a critical tool to increase energy density. On the other hand, excess ingestion of fat leads to a gain of excess weight (Shongwe et al., 2022). Partial replacement of orange-fleshed sweet potato with soybean flour has led to a general increase in the fat profile of the infant food. The fat profile of 100% OFSP infant food was (0.50±0.00%), the lowest among the samples. However, the fat profile increased significantly ($P<0.05$) after the soybean flour was incorporated into the infant food.

The fat profile ranges from (14.82±0.11% to 10.74±0.24%) at 80% to 70% soybean flour inclusion respectively. Decreasing the soybean flour inclusion by 2% (B-C) decreased the fat profile from (14.82±0.11% to 12.30±0.48%). However, sample F which contains 70% soybean flour had the lowest (10.74±0.24%) fat profile among the composite infant food. This may be due to the science that legumes store energy as fat/oil rather than as starch (Iwe et al., 2016), hence the fat content was high at 80% inclusion of soybean flour into the infant food. The results confirmed the study by Roger et al. (2022) that soybeans contain an appreciable amount of minerals and fat/oil. Infant food with high-fat content contributes significantly to the energy requirements of humans. The high-fat content of the soybean-orange-fleshed sweet potato composite infant food in this study would make it a better source of fat than other flour blends (Iwe et al., 2016).

Infant food with high-fat content is also good as flavour enhancer and useful in improving the palatability of food in which it is incorporated (Godswil, 2019). The results would be relevant for enhancing the utility of orange-flesh sweet potato and soybean flour in the food industry. Finally, since 80% had the maximum protein profile (33.11±0.13%) to meet the daily protein in children, the author recommends 80% soybean flour for infant food development.

Fibre Content

Fibre is crucial to consumer health contributing to the prevention of celiac disease including cancer, obesity, and cardiovascular disorders (Akubor, 2017).Dietary fibre intake is associated with reduced risk for the development of cardiovascular disease and mortality(Barber et al., 2020). A high intake of soluble dietary fibre appears to have additional metabolic benefits, including an improved glycemic index of carbohydrate foods and lipid profiles(Barber et al., 2020). The daily dietary fibre intake of children ranges from (25% to 30%) while that of adults falls within the range of (6% to 12%) as reported by Verem et al. (2021). Therefore, the fibre profile of orange-fleshed sweet potato-soybean composite infant food was determined as depicted in Table 3.

The fibre content of the control sample (100%OFSP) was 3.86±0.09%, the lowest among the samples. However, replacing orange-fleshed sweet potato with soybean flour has led to a significant ($p<0.05$) increase in the fibre profile of the infant food. The fibre profile of the composite infant food ranges from (8.87±0.12% to 7.56±0.38%) with 80% soybean flour recording the highest and 70% being the lowest mean value. It was noticed that decreasing the inclusion of soybean flour decreases the fibre profile of the infant food. At 80%, the fibre content was 8.87±0.12%, which reduced to 8.45±0.12% at 70% inclusion of soybean flour. However, a further decrease of soybean flour from 75% to 72% decreases the fibre content from 8.15±0.06% to 8.02±0.03%. Moreover, a further reduction in soybean flour from 72% to 70% significantly decreases the fibre content of the infant food from (8.02±0.03% to 7.56±0.38%) respectively. The decrease in fibre at a decrease in the soybean flour inclusion level may be caused by diluting the fibre source of soybean with low orange-fleshed sweet potato fibre of 3.16±0.08 in the infant food.

The increase in fibre content confirms the results of Iwe et al. (2016) that soybeans contain an appreciable amount of fibre which would elevate the fibre content when added to formulate a composite flour. The results of this research coincided with the findings of Oluwamukomi et al.(2011)including soybean flour increases the fibre content of wheat-cassava-soybean composite biscuits. A similar range of fibre content was reported by Godswil (2019) who stated that the fibre content of composite flour from varied grains increases after the fortification with soybean flour. Crude fibre reduces the release of glucose into the bloodstream and intra-colonic pressure decreasing the risks of colon cancer. These results may enhance the utility of soybean flour as a source of nutrients or reduce malnutrition in most middle-income nations.

Carbohydrate Content

Dietary carbohydrates serve as an energy source for human health and development. However, excessive intake of carbohydrate food leads to weight gain, and intake of low carbohydrate diets may result in weight loss. Also, consuming easily digestible carbohydrates such as sugar promotes obesity (Landry et al., 2021). Consequently, it necessitates modulating the level of carbohydrate diet intake to reduce the risk of weight gain and obesity (Landry et al., 2021). The carbohydrate profile of the orange-fleshed sweet potato-soybean composite infant food was determined as depicted in Table 2. The dietary carbohydrate profile of orange-fleshed sweet potato infant food was 78.54±0.20%, being the highest among samples with carbohydrate content.

However, introducing soybean flour has led to a significant ($p<0.05$) decrease in the carbohydrate profile of the infant food. The carbohydrate content of the composite infant food ranges from (27.65±0.08% to 43.19±0.65%) with 80% soybean flour recording the lowest and 70% having the highest carbohydrate profile. A further decrease in soybean flour inclusion from 78% to 75% leads to an increase in carbohydrate profile from (34.70±0.38% to 37.85±0.58%). Moreover, decreasing the soybean flour inclusion by 2% (F-E) further increased the carbohydrate profile from (39.16±0.73% to 43.19±0.65%). The results obtained from the raw ingredient indicate that the carbohydrate of the orange-fleshed sweet potato was higher (86.31±0.23%) than that of soybean flour (35.97±0.19%).

Therefore, the increase in carbohydrates may be due to the dilution effect of the orange-fleshed sweet potatoes. The low carbohydrate profile at higher levels of soybean inclusion may also result from the high protein, fibre, and fat/oil profile. Also, David et al. (2022) confirmed that legumes like cowpeas and soybeans are lower in carbohydrates than cereals. The results of this research coincided with findings reported by Oluwamukomi et al. (2011) that soybean flour-fortified biscuits had the lowest carbohydrate profile comparable to whole wheat flour biscuits. Although soybean flour inclusion decreases the carbohydrate content, the carbohydrate content of the infant food is high enough to meet the daily requirement of carbohydrates. Carbohydrates are good sources of energy (Butt & Batool, 2010).

A high concentration of carbohydrates is desirable in weaning formulas and breakfast meals. Moreover, the results may be relevant for enhancing the utility of soybean flour and orange-fleshed sweet potatoes in the food industry. The high carbohydrate content of the Soya bean-orange-fleshed sweet potato blend would make it a good source of energy in breakfast formulations (Butt & Batool, 2010).

Effects of Soybean Flour Enrichment on the Mineral Content of Orange-Fleshed Sweet Potato-Soybean Composite Flour Infant Food

Minerals perform several functions including, tissue maintenance, bone, and teeth formation, and aid in the regulation/coordination of the body function. From a nutritional standpoint, minerals are inorganic elements required as essential nutrients by humans to carry out functions necessary for life (Awuchi et al., 2020). However, these minerals cannot be biochemically synthesized by humans but are obtained by consuming animals, plant products, and drinking water (Awuchi et al., 2020). However, mineral deficiency causes several health implications and has been a public concern. For instance, iron, calcium, zinc, and vitamin deficiency are caused by prolonged shortages of nutritious diet or by infection such as intestinal worms(Mohammad ifard et al., 2019). Therefore, consumers are concerned about the mineral quality of food. Hence, the mineral profile of orange-fleshed sweet potatoes composite infant food was assessed as depicted in Table 4.

Phosphorus Profile

The phosphorus profile of the orange-fleshed sweet potatoes infant food ranges from (2340.82±15.75ug/g to 6244.74±19.24ug/g), 100%OFSP infant food recorded as the lowest while 80% inclusion of soybean flour had the highest mean average of phosphorus profile. The inclusion of soybean flour has led to an increase in the phosphorus profile. However, increasing the inclusion of soybean flour from 80% to 70% significantly decreases the phosphorus profile. Hence, at 80% soybean flour inclusion, the phosphorus profile was (6244.74±19.24ug/g), and decreased to 5754.07±9.75ug/g at 78%. However, a further decrease in soybean flour addition to 75% reduces the phosphorus content to 5678.04±26.14ug/g. notwithstanding, 70% soybean flour inclusion resulted in a low phosphorus profile in the infant food. The results agree with those reported by Verem et al. (2021) that at 20% inclusion of soybean flour, the phosphorus profile was higher than the only wheat flour. Furthermore, the results confirmed the report by

Roger et al. (2022) that crops like legumes contain an appreciable amount of minerals and essential elements than cereals. A low intake of phosphorus leads to rickets or osteomalacia due to the release of calcium from the skeleton systems while a high intake of phosphorus leads to complexes that reduce serum calcium, stimulating parathyroid hormone (PTH), which, in turn, causes bone desorption and returns serum calcium to homeostatic concentrations (Verem et al., 2021). Therefore, infant food with maximum phosphorus may help reduce malnutrition and its associated problems in countries with high malnutrition problems.

Iron Content

Iron content depicts the levels of essential minerals in the food, relevant in boosting the formulation of red blood cells since iron helps the production of red blood cells (Khoshgozaran-Abras et al., 2014). The iron profile of orange-fleshed sweet potato infant food was assessed as shown in Table 3. Introducing soybean in orange-fleshed sweet potatoes significantly impacts the infant food's iron profile. The results showed that 100% OFSP infant food recorded the lowest iron profile (578.95±8.34ug/g). In general, the iron profile of soybean flour-enriched infant food ranges from (1212.49±4.19ug/g to 629.73±8.36ug/g). Sample B with 80% soybean flour had the highest while sample F with 70% had the lowest iron profile.

However, increasing the inclusion of soybean flour from 78% in sample C to 75% in sample D does not significantly decrease the iron profile of the infant food. The higher the soybean flour, the higher the iron profile in the infant food. In general, the increase in the iron profile may be caused by the inclusive effects of soybean flour. The results concord with the findings reported by Erben and Osella (2017) on the fortification of bread with soybean flour which stated that increasing the inclusion of soybean flour led to a progressive elevation of the iron profile of the bread. Similarly, the results of the study reported by Verem et al. (2021)increasing the soybean addition during the formulation of wheat-soybean-moringa composite flour increased the iron profile of the composite flour. Iron deficiency has increased recently due to low iron-rich diet intake in developing nations.

However, although shrimp was added at 10% for all the samples, a study reported by Jeyakumari et al. (2016) confirmed that shrimp contain a considerable amount of essential minerals which may also positively impact the iron profile of the infant food. The iron-sufficient infant food would be relevant for reducing iron deficiency problems in Ghana while enhancing the utility of orange-fleshed sweet potatoes and soybean flour in the food industry.

Potassium Profile

High dietary potassium is associated with a decrease in blood pressure, particularly in a high-sodium diet(Weaver, 2013). Recently the intake of food rich in minerals has been on the rise. Potassium helps prevent stroke coronary heart disease and high blood pressure (Landry et al., 2021). The potassium content of the infant food ranges from (7300ug/g to 11708.15±125.05ug/g).

The result shows that 100% OFSP infant food had the lowest (7300.69±36.76ug/g) potassium profile while 80% measured the highest (11708.15±125.05ug/g) potassium profile. Decreasing the soybean flour inclusion influences the potassium profile of the infant food. Hence, at 78% of soybean flour, the potassium profile was 10513.01±273.20ug/g, decreased to

9710.54±95.60ug/g at 75% soybean flour inclusion and further reduced to 9345.32±47.28ug/g or 9118.81±9.35ug/g when decreasing the soybean flour inclusion level to 72% or 70% respectively. The high potassium profile at higher levels of soybean flour may be caused by the addition of soybean flour which contains an appreciable amount of minerals than orange-fleshed sweet potatoes. Comparatively, legume crops like soybeans and cowpeas were reported by Olaoye et al. (2006) to contain more minerals than cereals and would elevate the potassium profile when fortified with cereals crops. The results agree with the findings of Roger et al. (2022) that including soybean flour increases the potassium profile of potato-soybean composite flour. Salari Moghaddam et al. (2014) reported an increase in the potassium content of bread with an increase in the inclusion of soybean flour. The results suggest that the orange-fleshed sweet potatoes-soybean composite infant food would solve malnutrition in most developing nations.

Table 4: Effects of Soybean Flour Enrichment on the Mineral Profile of Orange-Fleshed Sweet Potato-Soybean Composite Flour Infant Food

CODE	SBF: OFSPF: SPF (%)	P ug/g	Fe ug/g	K ug/g	Zn ug/g
A	00:100:00	2340.82±15.75[f]	578.95±8.34[e]	7300.69±36.76[e]	137.93±2.25[f]
B	80:10:10	6244.74±19.24[a]	1212.49±4.19[a]	11708.15±125.05[a]	197.90±0.56[a]
C	78:12:10	5754.07±9.75[b]	1169.05±26.93[b]	10513.01±273.20[b]	191.48±0.02[b]
D	75:15:10	5678.04±26.14[c]	1165.62±8.90[b]	9710.54±95.60[c]	178.44±0.07[c]
E	72:18:10	5557.99±18.77[d]	689.94±7.88[c]	9345.32±47.28[d]	153.44±0.21[d]
F	70:20:10	5267.96±18.55[e]	629.73±8.36[d]	9118.81±9.35[d]	150.20±0.28[e]

Source: Author's construct, 2024.
Mean values in a column that do not share the same letter are significant ($p<0.05$) different

Zinc Profile

Clinically, Zn deficiency affects various organs in the gastrointestinal, epidermal, immune, central nervous, skeletal, and reproductive systems(Liu et al., 2020). Zn supplement has a positive impact on the reduction of Zn deficiency like diarrheal episodes and diarrhea-induced morbidity, premature delivery, and acute infection of the lower respiratory tract; and it also builds on the linear growth and weight gain in children(Sangeetha et al., 2022). Zinc content (Zn) balances body fluids' pH and promotes collagen formation (skin, hair, and nails).It also enhances mental prowess and memory(Sangeetha et al., 2022). Therefore, the zinc profile of the infant food from orange-fleshed sweet potatoes was determined as shown in Table 4. The zinc profile of the 100% OFSP infant food was 137.93±2.25ug/g.

However, including soybean flour has led to a general increase in the zinc profile of infant food. Hence, at 80% addition of soybean flour, the zinc profile was 197.90±0.56ug/gand decreased to 191.48±0.02ug/g at 78% soybean inclusion. Also, a further decrease in soybean flour to 75% leads to a progressive reduction in the zinc content of infant food to 178.44±0.07ug/g. Further decreasing the inclusion of flour to 72% or 70% reduces the zinc profile to 153.44±0.21ug/g or 150.20±0.28ug/g respectively. The inclusion effects of soybean flour in infant food may cause a general increase in the zinc profile. Also, decreasing the soybean flour inclusion means a portion of the rich mineral of soybean is taken and replaced with the low-rich mineral of orange-fleshed sweet potatoes.

Several studies reported that soybeans contain sufficient minerals such as zinc (Sanful & Darko, 2010). The results confirmed the study reported by Taghdir et al. (2017) that the mineral content of legume crops is higher than cereal crops. Similarly, Roger et al. (2022)reported the same range of zinc profile in biscuits fortified with soybean flour. The results suggest that soybean flour would alternatively elevate the zinc profile of composite flour when included, which may help reduce malnutrition in developing nations.

Vitamin C and Beta-carotene profile of Orange-Fleshed Sweet Potato-Soybean Composite Flour Infant Food

Vitamin C Profile

Vitamin C is essential to human health as it helps to increase the production of white cells and the proper level of interferon (Taraj et al., 2021). Vitamin C is relevant in preventing cancers, and cardiovascular disease. Studies show that consuming more diet with high vitamin C can increase the antioxidant profile by 30%, helping the body fight against inflammation (Taraj et al., 2021). Therefore, infant food with high vitamin C may be relevant for reducing problems associated with vitamin C deficiency. Hence, the vitamin C profile of orange-fleshed sweet potato-soybean composite infant food was determined as depicted in Table 5. The results showed that the 100% OFSP infant food recorded the lowest vitamin C (4.14±0.12mg/100g).

However, after the soybean flour inclusion, the vitamin C profile increases between (12.53±0.39mg/100gto 5.92±0.20mg/100g), with 80% soybean flour inclusion recording the highest and 70% having the lowest among the samples. It was noticed that decreasing the soybean inclusion has a significant ($p<0.05$) effect on the vitamin C profile of the infant food. Hence, at 78% soybean flour inclusion, the vitamin C decreases to 10.58±0.27mg/100g and further decreases to 9.12±0.16mg/100g or 6.76± 0.19mg/100g at a decrease of soybean flour from 75% to 72% respectively.

Notwithstanding, a further decrease in soybean flour inclusion to 70% leads to a further decrease in the vitamin C profile to 5.92±0.20mg/100g. The inclusive effects of soybean flour may cause an increase or decrease in the vitamin C profile of the infant food. Studies reported by Stešková et al. (2006) confirmed that soybeans contain considerable vitamins including vitamin C after fortifying milk with soybean flour. These results agree with the findings of Farzana and Mohajan (2015), the vitamin C profile of biscuits fortified with soybean flour recorded a higher vitamin C profile than wheat flour biscuits. Notwithstanding, Olubunmi et al. (2017) reported a similar increase in the vitamin C profile after fortifying maize-millet complementary food with soybean flour. Moreover, infant food with maximum retention of vitamin C may help reduce vitamin C deficiency in most developing nations including

Ghana. The results suggest orange-fleshed sweet potatoes-soybean flour infant food may serve as an alternative vitamin C source for children.

Table 5: Vitamin C and Beta-Carotene Profile of Orange-fleshed Sweet Potatoes-Soybean Composite Infant Food

CODE	SBF: OFSPF: SPF (%)	Vitamin C mg/100g	Beta carotene mg/100g
A	00:100:10	4.14±0.12[f]	23.95±0.24[a]
B	80:10:10	12.53±0.39[a]	15.91±0.15[f]
C	78:12:10	10.58± 0.27[b]	17.46±0.15[e]
D	75:15:10	9.12± 0.16[c]	18.64±0.13[d]
E	72:18:10	6.76± 0.19[d]	20.10±0.18[c]
F	70:20:10	5.92±0.20[e]	21.22±0.37[b]

Source: Author's construct, 2024.

Mean values in a column that do not share the same letter are significantly ($p<0.05$) different

Beta-Carotene Profile

βeta-Carotene, which is converted to vitamin A by the human body when consumed, is abundant in orange-fleshed sweet potato (OFSP) and has the potential to combat the VAD when consumed in considerable quality. This supports the findings of Laurie et al. (2018), who reported that orange-fleshed sweet potatoes are rich in beta-carotene.

Therefore, the beta-carotene profile of orange-fleshed sweet potatoes-soybean infant food was determined. The results indicate that the 100%OFSP infant food recorded a maximum beta carotene of (20.10±0.18mg/100g). The inclusion of soybean flour into orange-fleshed sweet potatoes infant food has increased the beta-carotene of infant food range from (15.91±0.15mg/100g to 21.22±0.37mg/100g). It was observed that decreasing the soybean flour inclusion led to an increase in the beta-carotene profile.

Decreasing soybean flour inclusion means that more orange-fleshed sweet potatoes were added, increasing the beta-carotene profile of the infant food. Also, soybean flour does not contain beta-carotene, with higher inclusion of soybean, the infant food attains low beta-carotene. The results coincide with the findings reported by Stešková et al. (2006) that beta-carotene of soybean flour was low and insignificant in infant food fortified with soybean flour. Similar results were reported by Farzana and Mohajan (2015) soybean flour contains no beta-carotene profile and may not significantly impact the beta-carotene profile of biscuits fortified with soybean flour. Moreover, the high beta-carotene may be due to the addition of orange-fleshed sweet potatoes.

Consumer Acceptance of Orange-Fleshed Sweet Potato-Soybean Infant Food

Appearance Acceptance

The average panelists' ratings of the sensory attributes of the orange-fleshed sweet potatoes-soybean composite infant food were assessed as depicted in Table 6 below. The consumer acceptance of the infant food was evaluated using 5 hedonic scales (1-very dislike to 5-very liked). Appearance remains a physical attribute of food products that influences consumer preference and willingness to purchase the product (Farzana & Mohajan, 2015). After the sensory exercise, it was observed that consumer ratings of the 100% OFSP infant food was 2.92, the lowest among the samples. The results show that the fortification of the already orange-fleshed sweet potato infant food with soybean flour significantly ($p<0.05$) increases the appearance of the composite infant food. Hence, at 70% soybean flour inclusion, the average consumer rating in appearance was 3.49, which increased to 4.00 at 72% soybean flour inclusion. However, a further increase in the inclusion of soybean flour to 75% has increased the appearance rating of consumer acceptance to 4.02, and 4.08 at 78% inclusions.

Notwithstanding, further increasing soybean flour inclusion to 80% has led to a significant increase in consumer acceptance of the infant food appearance. The increase in consumer ratings of the appearance may be attributed to the attractive bright colour of soybean flour. Also, the low ratings for a decrease in soybean flour may probably be due to the unattractive dull appearance colour of orange-fleshed sweet potatoes. These results agree with the findings of Emmanuel-Ikpeme (2012) that the consumer acceptance of tiger nut infant food fortified with soybean flour was higher than tiger nut infant food. Similarly, Abolaji et al. (2019) reported increases in consumer acceptance of sorghum-African yam-soybean composite flour appearance after a sensory exercise with 50 semi-trained panellists. Moreover, Nwakalor et al.(2014) established that sorghum-based weaning food fortified with soybean flour recorded high consumer ratings of acceptance in appearance. The results suggest that soybean flour would be an alternative for enhancing the appearance of infant food.

Aroma Acceptance

Aroma is one of the first characteristics perceived by consumers by their olfactory senses when food is bought. The aroma remains a physical parameter that influences the consumer acceptance of food or products (Abolaji et al., 2019). After the sensory exercise, it was observed that the consumer acceptance of the unfortified soybean flour infant food was 2.74, which increases to a range of 3.88 to 3.23 after fortifying with soybean flour. However, increasing the soybean flour inclusion has a significant ($p<0.05$)

effect on the consumer's acceptance of the infant food aroma. Hence, at 70% inclusion, on average, the mean score of aroma acceptance was 3.23 which later increased to 3.31 at 72% inclusion of soybean flour.

However, a further increase in soybean flour from 75% to 78% increased consumer acceptance of the infant food aroma from 3.49 in sample D to 3.85 in sample C. Notwithstanding, 80% soybean flour inclusion recorded the highest ratings of consumer aroma acceptance of the infant food. In general, the increase in consumer acceptance of the infant food aroma may be caused by the inclusive effect of soybean flour. The results of this research agree with the findings reported by Roger et al. (2022) that the consumer aroma acceptance of sweet potato biscuits fortified with soybean flour was much higher than 100% sweet potato biscuits. Similarly, Olubunmi et al. (2017) reported that millet-maize complementary food fortified with 20% soybean flour was highly accepted compared to the unfortified complementary food. Furthermore, Salari Moghaddam et al. (2014) confirmed that soybean flour has some intrinsic aroma properties and thus, fortifying bread with 50% soybean flour recorded the highest (7.62) consumer ratings of bread aroma. Therefore, it may be interesting to know that soybean flour has the potential to enhance the aroma acceptability of food products.

Taste Acceptance

The taste is the combined effects of saltiness, sourness, bitterness, and sweetness attributes of food after swallowing play a key role in its acceptance by consumers (Paraskevopoulou et al., 2012). After sensory exercise, the consumer acceptance of taste varied from 2.89 in sample A to 4.05 in sample B. The results show that introducing soybean flour in an already orange-fleshed sweet potato infant food significantly affects consumer acceptance of the taste of the infant food. It was noticed that the taste acceptance of the unfortified infant food was 2.89, being the lowest among the samples. However, fortifying the infant food with 70% soybean flour led to a low rating of consumer acceptance of taste (3.31), but increased to 3.58 at 72% inclusion of soybean flour. To transgress, increasing the soybean flour from 75% to 78% leads to a progressive increase in the consumer ratings of the taste from (3.82 to 3.92) respectively. Notwithstanding, at 80% soybean flour inclusion, on average, the mean score of consumer acceptability of infant food in terms of taste was higher (4.05) compared to all the samples.

The increase in consumer acceptance of the infant food taste can be ascribed to the intrinsic sweet taste of soybean flour. Also, soybean flour contains high fat enhances the flavour and palatability of the infant food. The results are similar to the findings reported by Taghdir et al. (2017) that on average, the mean score of taste acceptance of gluten-free bread fortified with soybean flour was much higher than the unfortified bread. Similarly, Erben and Osella (2017) confirmed that pea and whey bread fortified with soybean flour increases consumer ratings of taste acceptance after the sensory evaluation was conducted. Moreover, Sanful and Darko (2010) explored consumer acceptance of wheat bread fortified with soybean flour and reported that as more and more of soybean flour is added to wheat flour, on average, the mean score of taste acceptance of the bread increases more than the unfortified bread. These results suggest that soybean flour has sweet intrinsic properties and has the potential to enhance the taste of food.

Table 6: Consumer Acceptance of Orange-Fleshed Sweet Potato-Soybean Composite Flour Infant Food

CODE	SBF: OFSPF: SPF (%)	Appearance	Aroma	Taste	Texture	Overall Accept.
A	00:100:10	2.92±1.59^{f}	2.74±1.34^{f}	2.89±1.52^{f}	2.92±1.46^{f}	3.17±1.63^{f}
B	80:10:10	4.11±0.90^{a}	3.88±1.11^{a}	4.05±1.02^{a}	3.95±0.98^{a}	4.29±1.16^{a}
C	78:12:10	4.08± 0.91^{b}	3.85±0.85^{b}	3.92±0.96^{b}	3.68±1.00^{b}	4.15±0.91^{b}
D	75:15:10	4.02±0.86^{c}	3.49±1.29^{c}	3.82±1.07^{c}	3.52±1.05^{c}	4.03±1.00^{b}
E	72:18:10	4.00±0.71^{d}	3.31±1.14^{d}	3.58±1.39^{d}	3.43±1.37^{d}	4.00±1.29^{d}
F	70:20:10	3.49±1.26^{e}	3.23±1.37^{e}	3.31±1.37^{e}	3.38±1.11^{e}	3.75±1.10^{e}

Source: Author's construct, 2024.
Mean values in a column that do not share the same letter are significantly ($p<0.05$) different

Texture Acceptance

The texture is the combined impact of (roughness and smoothness), of infant food when felt between fingers, plays a key role in consumer acceptability of infant food (Park et al., 2021). After the sensory exercise, it was observed that the texture acceptance of the infant food varied from 2.92 in sample A to 3.95 in sample B. The results show that the inclusion of soybean flour has a significant ($p<0.05$) effect on the texture acceptance of the infant food. Hence, on average, the consumer acceptance in terms of texture of the unfortified soybean infant food was 2.92, which increased to 3.75 when 70% soybean flour was added. However, a further increase in soybean flour inclusion to 72% further increases the consumer texture acceptance of the infant food to 3.43 or 3.52 at a 75% inclusion level. Also, as more and more soybean flour is added, the texture acceptance increases.

Hence, at 78% soybean flour inclusion, the texture ratings of the infant food increase to 3.68 and further to 3.95 at 80% soybean flour inclusion. The general increase in the texture acceptance of the soybean flour fortified infant food could be due to the finer flour particle size properties of soybean flour when milled, which enhance the smoothness of the infant food between fingers. Studies by Verem et al. (2021)reported that the functional properties of soybean flour have high solubility power in water, which enhances the smoothness of orange-fleshed sweet potatoes-soybean composite infant food. The results of this research collaborate with the findings reported by Abolaji et al. (2019) who stated an increase in consumer texture acceptance of sorghum and African yam bean composite flour fortified with soybean flour.

Also, Olubunmi et al. (2017) stated that maize-millet complementary food fortified with soybean flour showed higher consumer acceptance in terms of texture over 100% maize-millet complementary food. Moreover, it would be interesting to know that, according to Farzana and Mohajan (2015), increasing the inclusion of soybean flour from 10% to 20% in wheat flour biscuits leads to a significant rise in the texture acceptance by 30% over the 100% wheat flour biscuits. Therefore, the results suggest that soybean flour would be an alternative flour for enhancing the consumer texture acceptability of infant food and other products.

Overall Acceptance

The overall acceptability (combined effect of appearance, texture, taste, and aroma) of infant food plays an imperative role in its consumer acceptance (Paraskevopoulou et al., 2012). After sensory exercise, it would be interesting to know that the overall acceptance of the infant food ranges from

3.17 in the control sample (A) to 4.29 in the soybean flour-fortified samples (B). Therefore, the results show a significant ($p<0.05$) effect on the overall acceptance of the infant food when soybean flour was added. Hence, at 70% soybean flour inclusion, on average, the mean score of consumer overall acceptance of the infant food was 3.75, which further increased to 4.00 at 72%, and later to 4.03 at 75% addition of soybean flour. Notwithstanding, a further increase of soybean flour from 78% to 80% further increases the consumer overall acceptability of the infant food from 4.15 to 4.29 with sample B (80:10:10) of orange-fleshed sweet potatoes recording the highest among the samples.

The general increase in the overall acceptance of the infant food may be attributed to the combined effects of appearance, aroma, taste, and texture acceptance of the infant food. These results coincided with a report by Sanful and Darko (2010) that the average mean scores of bread's overall acceptability increased from 6.00 to 7.98 at 10% to 50% inclusion of soybean flour. Similarly, Length (2013) reported an increase in the consumer overall acceptance (6.20 to 6.89) of tapioca fortified with an increase in soybean flour from 10% to 40% respectively. Moreover, Nwakalor. (2014) reported that incorporating soybean flour into sorghum-based weaning food exhibited higher acceptance by 50 semi-trained panelists after sensory evaluation. These results suggest that soybean flour has the potential to enhance consumer acceptance of food when incorporated into food or other products. Finally, soybean seeds are highly produced in Ghana. Therefore, fortifying infant food with soybean flour would extend the utility of soybean flour in the food industry, reduce malnutrition problems, hinder hunger and poverty, and improve food security in most developing nations.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

Vitamin A deficiency is a health problem in most developing countries, including Ghana. It is associated with night blindness. Also, studies reported that 32% of children under five years are estimated to be Vitamin A deficient. In Ghana, vitamin A deficiency is of particular concern, accounting for 72% of the population. Therefore, several studies reported that diets such as fruits, leafy vegetables, fish, and animal products can provide vitamin A to solve the vitamin A deficiency in Ghana. Also, crops such as tomatoes, carrots, orange-fleshed sweet potatoes, and shrimp contain beta-carotene, a precursor of vitamin A that can help prevent vitamin A deficiency in Ghana. To reduce the prevalence of vitamin A deficiency, orange-fleshed sweet potatoes were processed into infant food, serving as one of the staple foods for children in Ghana and other developing countries. However, being rich in beta-carotene, a precursor of vitamin A does not mean infant food produced contains all the nutrients in a balanced stage. For instance, orange-fleshed sweet potatoes contain less protein and other essential elements than soybean flour. Therefore, fortifying orange-fleshed sweet potatoes with soybean flour would enhance the nutrient attributes of the food. Although, soybean flour can enhance the nutrient attribute of the food, replacing a greater proportion of orange-fleshed sweet potatoes with soybean flour may alter the consumer acceptability.

Therefore, to compensate for micro and macro-nutrients and bioactive compounds, shrimps were reported to be the best vehicle for micro and macro-nutrients. However, fortification in the food industry has not been exhausted.

Notwithstanding, to enhance the flavour or palatability of the infant food, species such as onion, and tomatoes known for their aroma improvement would improve the consumer acceptability of the infant food. Therefore, the study explores the utilization of soybean flour and orange-fleshed sweet potatoes-shrimp composite infant food and a small addition of tomatoes, or onion. To achieve the various formulations, Minitab software with simple centroid was used; 80%:10%, 78%:12%, 75%:15%, 72%:18%, and 70%:20% of soybean-orange-fleshed sweet potato composite flour. However, 100% of orange-fleshed sweet potato was used as a control sample while 10% of shrimp was added to all the samples. Notwithstanding, 5g of tomatoes and onions were added to all the samples. Functional properties such as bulk density, swelling capacity, water/oil absorption capacity, and solubility index of the flour were assessed to determine the flour's workability. Also, formulation based on soybean and orange-fleshed sweet potato was used to develop the food and analyses like nutritional composition, mineral content, and sensory qualities were carried out. The data was statistically analyzed using Minitab software where means and standard deviation were obtained at confidence levels of 95%. Finally, it was observed that;

1. The fortification of orange-fleshed sweet potato with soybean flour has led to a significant increase in the bulk density of the orange-fleshed sweet potato-soybean composite flour. Hence, at 70% inclusion of soybean flour, bulk density was 0.63±0.00g/cm^3 which increased to 0.69±0.01g/cm^3 at 80% addition of soybean flour.
2. Fortifying orange-fleshed sweet potato infant food with soybean flour significantly increases the swelling capacity of the orange-fleshed

sweet potato-soybean composite infant food. Thus, at 80% inclusion of soybean flour, the swelling capacity was 17.17±0.05, whereas at 70%, soybean flour, the swelling capacity was 17.89±0.09, being the highest among the samples.

3. The water absorption capacity of orange-fleshed sweet potato infant food significantly increased when soybean flour was added. Hence, at 80% soybean flour addition, the water absorption capacity was 229.63±0.35% increasing to 244.07±0.13% at a decrease in soybean flour to 70%. The increase in water absorption capacity of the samples follows the pattern (A<C<D<E<B<F).
4. Increasing the inclusion of soybean flour from 70% to 80% has led to a general decrease in the oil absorption of the composite infant food. Therefore, at 70% soybean flour addition, the average oil absorption capacity was 255.49±0.73%, decreased to 217.33± 2.39% at 80% addition of soybean flour. Oil absorption capacity generally increased with sample F recording the highest OAC%.
5. There was a general increase in the solubility index of orange-fleshed sweet potato infant food fortified with soybean flour. Hence, at 70% soybean flour, the solubility index was 18.15±0.15 whereas 80% soybean flour inclusion recorded 17.25±0.06 solubility index. However, 78% soybean flour addition had the lowest solubility index among the samples.
6. Decreasing the inclusion of soybean flour significantly reduces the moisture content of the soybean-orange-fleshed sweet potato infant food. Hence, the moisture content of the composite infant food ranges

from (10.39±0.17% to 8.78±0.20%). However, 80% of inclusion had the highest moisture while 70% recorded the lowest moisture content.

7. Fortifying orange-fleshed sweet potato infant food with soybean flour has led to a general increase in the ash profile of the composite infant food. Hence at 70% addition of soybean flour, the ash profile was 4.44±0.19% which increased to 5.16±0.22% at 80% inclusion of soybean flour.
8. Increasing the inclusion of soybean flour has led to a significant increase in the protein profile of soybean-orange-fleshed sweet potato-shrimp infant food. Hence at 70% soybean flour inclusion, the protein content was 25.25±0.12% more than the control sample but lower than 80% soybean flour inclusion (33.11±0.13%).
9. The fat/oil profile increases significantly at an increase in the inclusion of soybean flour in the orange-fleshed sweet potato infant food. Hence, the fat/oil profile was lower (10.74±0.24%) at 70% soybean flour while 80% had the highest fat/oil profile (14.82±0.11%) respectively.
10. Adding soybean flour significantly increases fibre profile of soybean-orange-fleshed sweet potato composite infant food. Therefore, at 70% soybean flour inclusion, the fibre content was 7.56±0.38%, higher than 100% orange-fleshed sweet potato while less than 80% (8.87±0.12%) addition of soybean flour.
11. The carbohydrate profile of the soybean-fortified infant food decreases significantly at an increase in the inclusion of soybean flour. Thus, at 70% inclusion of soybean flour, the average carbohydrate profile was

(43.19±0.65%), which decreased significantly to 27.65±0.08% when 80% of soybean flour was added.

12. The phosphorus profile of the orange-fleshed sweet potato infant food was improved after adding the soybean flour. Hence, the phosphorus profile ranges between (6244.74±19.24ug/g and 5267.96±18.55ug/g). However, phosphorus profile was high at 80% (6244.74±19.24ug/g) and low at 70% (5267.96±18.55ug/g) addition of soybean flour.
13. The iron profile increases significantly after fortifying orange-fleshed sweet potato infant food with an increase in soybean flour. Therefore, the iron content of the composite infant food ranges between (1212.49±4.19ug/g and 629.73±8.36ug/g) at a decrease in soybean flour addition from 80% to 70% respectively.
14. The potassium profile increases significantly after fortifying orange-fleshed sweet potato infant food with soybean flour. Thus, the potassium profile increases from 9118.81±9.35ug/g in sample F (70%) soybean flour to 11708.15±125.05ug/g in sample B (80%) addition of soybean flour.
15. Fortifying orange-fleshed sweet potato infant food significantly increases the zinc profile of the composite infant food. Hence, at 70% addition of soybean flour, on average, the zinc profile ranges from 150.20±0.28ug/g which increased to 197.90±0.56ug/g at 80% inclusion of soybean flour.
16. The vitamin C profile was improved after fortifying the orange-fleshed sweet potato infant food with soybean flour. Hence, the vitamin content ranges (12.53mg/100g to 5.92mg/100g). However, at 70%

inclusion of soybean flour, the vitamin C profile is 5.92±0.20mg/100g, which increases to 12.53±0.39mg/100g at 80% soybean flour.

17. The beta-carotene of the orange-fleshed sweet potato infant food fortified with soybean flour decreases at an increase in the inclusion of soybean flour. Hence, beta-carotene ranges from (21.22mg/100g to 15.91mg/100g). Soybean flour does not contain insufficient beta-carotene and may not significantly affect the beta-carotene level. However, the influence was caused by the orange-fleshed sweet potato.
18. The consumer acceptability of the soybean-orange-fleshed sweet potato infant food in terms of appearance was higher than the unfortified soybean flour infant food. Hence, on average, the mean score of consumer ratings of the unfortified soybean flour was 2.92, which increases to a range between (3.49 and 4.11). However, 70% of soybean flour inclusion had the lowest while 80% had the highest consumer acceptance in appearance.
19. Fortifying orange-fleshed sweet potato infant food with soybean flour has led to a general increase in consumer aroma acceptance of composite infant food. Hence, consumer acceptance of unfortified infant food was 2.74 in aroma acceptance. However, soybean flour addition increased on average, and the aroma acceptance ranged between (3.23 to 3.88), with 80% attaining the highest aroma acceptance while 70% had the lowest aroma acceptance.
20. The enrichment of orange-fleshed sweet potato with soybean flour has led to a general increase in consumer acceptance of the taste of the infant food. Hence, the average mean score of consumer acceptance of

the unfortified infant food was the lowest (2.89). Also, the fortification, the taste acceptance on average ranges between (4.05 to 3.31) with a decrease in soybean flour from 80% to 70%.

21. The texture acceptance was improved after fortifying orange-fleshed sweet potato infant food with soybean flour. Therefore, consumer acceptability on average, of the 100% orange-fleshed sweet potato recorded the lowest (2.92) among the samples. However, consumer texture acceptance increased with an increase in soybean flour addition. Hence, at 70% soybean flour, on average, consumers' texture acceptance was 3.38, which increases to 3.95 at 80% soybean flour addition.
22. Finally, there was an improvement in the overall acceptance of the orange-fleshed sweet potato infant food after fortifying it with soybean flour. Hence, consumer acceptance of the 100% orange-fleshed sweet potato infant food was the lowest (3.17), while the soybean-orange-fleshed sweet potato infant food's overall acceptance ranges between (3.75 to 4.29) at an increase in soybean flour from 70% to 80% respectively.

Hypothesis 1:

There is no statistically significant difference between the functional properties of the fortified developed baby food product and non-fortified flour.

Findings:

- Bulk density, swelling capacity, water absorption capacity, oil absorption capacity, solubility index, and moisture content all changed significantly with soybean flour fortification.

- In nearly all cases, increasing soybean flour led to measurable and statistically significant changes (increases or decreases) in these functional properties.

Interpretation:

Since fortification with soybean flour caused significant changes in these functional properties, there is a statistically significant difference between the fortified and non-fortified flours.

Conclusion:

Reject the null hypothesis.

Fortification with soybean flour significantly affected the functional properties of the orange-fleshed sweet potato baby food.

Hypothesis 2:

There is no statistically significant difference between the nutritional composition of the fortified developed baby food and non-fortified flour.

Findings:

- Protein, fat, fibre, ash, vitamin C, iron, zinc, phosphorus, and potassium all increased significantly with soybean fortification.
- Carbohydrate and beta-carotene levels decreased significantly as soybean flour increased.
- These differences were clear and consistent across inclusion levels (70–80%).

Interpretation:

Because fortification resulted in significant improvements (or reductions) in multiple nutritional parameters, the nutritional composition of the fortified samples differs significantly from the non-fortified flour.

Conclusion:

Reject the null hypothesis.

Soybean flour fortification significantly improved the nutritional composition of the baby food compared with non-fortified flour.

Hypothesis 3:

There is no statistically significant difference among the sensory attributes of the various proportions of fortified composite baby food.

Findings:

- All sensory attributes (appearance, aroma, taste, texture, and overall acceptability) increased significantly with fortification.
- Mean scores rose from approximately 2.7–3.2 in unfortified samples to 3.4–4.3 in fortified ones.
- The 80% soybean inclusion consistently showed the highest consumer acceptability across attributes.

Interpretation:

Since sensory attributes improved significantly as the proportion of soybean flour increased, there are clear differences among the fortified samples.

Conclusion:

Reject the null hypothesis.

There are statistically significant differences in sensory attributes among the various proportions of fortified composite baby food, with 80% soybean flour showing the best overall sensory acceptance.

Overall Summary Table

Hypothesis	Reason/Findings
H_1: Functional properties	Fortification caused significant changes in bulk density, swelling, and absorption properties.
H_2: Nutritional composition	Significant differences were observed in protein, fat, fibre, ash, vitamins, and minerals.
H_3: Sensory attributes	Significant differences observed across sensory parameters; 80% soybean inclusion rated highest.

Conclusion

Based on the results obtained, the following conclusion was drawn:

1. This study revealed that orange-fleshed sweet potato infant food can be fortified with soybean flour, shrimp, tomatoes, and onion without affecting its olfactory qualities. The product can help reduce vitamin A deficiency and improve protein quality.
2. Varying the proportion of soybean flour in OFS infant food has been shown by the study to impact the functional properties (bulk density, swelling capacity, solubility index, and water/oil absorption capacity).
3. Varying the proportion of soybean flour in OFS infant food has been proven to impact the nutritional composition (protein, fat, fiber, and carbohydrate) profile, mineral (phosphorus, potassium, iron, and zinc profile of the composite infant food.
4. Increasing the proportions of soybean flour inclusion in OFS infant food has been shown to impact the consumer acceptability of the composite infant food.

Recommendation

The following recommendation was made based on the results obtained:

1. To optimize the nutritional composition, mineral content, and consumer acceptability of soybean-orange-fleshed sweet potato infant food, the author recommends 80% soybean flour addition. However, further research should focus on the impact of soybean flour inclusion on the glycemic load and glycemic index of the food.
2. Finally, further research should be conducted on varying the proportion of shrimp and onion and their impact on the nutritional and consumer acceptability of confectionery like bread, biscuits, and doughnuts.

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APPENDIX

APPENDIX A

ETHICAL CLEARANCE LETTER

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

TEL: [illegible]
E-MAIL: [illegible]
OUR REF: IRB/C3/Vol.1/0604
YOUR REF:
OMB NO: 0990-0279
IORG #: IORG0011497

15TH JANUARY, 2024

Ms Melody Dumagu
Department of Vocational and Technical Education

University of Cape Coast Dear Ms Dumagu

ETHICAL CLEARANCE - ID (UCCIRB/CES/2023/157)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted Provisional Approval for the implementation of your research **Nutritional Analysis of Formulated Infant Food Using Sweet Potatoes, Soybeans, and Shrimps.** This approval is valid from **15th January 2024 to 14th January 2025.** You may apply for an extension of ethical approval if the study lasts for more than 12 months.

Please note that any modification to the project must first receive renewal clearance from the UCCIRB before its implementation. You are required to submit a periodic review of the protocol to the Board and a final full review to the UCCIRB on completion of the research. The UCCIRB may observe or cause to be observed procedures and records of the research during and after implementation.

You are also required to report all serious adverse events related to this study to the UCCIRB within seven days verbally and fourteen days in writing.

Always quote the protocol identification number in all future correspondence with us about this protocol.

Yours faithful,

Kofi F. Amuquandoh

Ag. Administrator

ADMINISTRATOR
INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF CAPE COAST

APPENDIX B
INTRODUCTORY LETTER

UNIVERSITY OF CAPE COAST
COLLEGE OF EDUCATION STUDIES
FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

TELEPHONE: 03212299210
E-MAIL: votec@ucc.edu.gh

Department of Vocational and Technical Education
University Post office
Cape Coast

Our Ref: VTE/I1AP/V.4/63

Your Ref:

8th March, 2024.

The Regional Director
Ghana Health Service
Greater Accra Regional Director
Accra

Dear Sir/Madam,

INTRODUCTORY LETTER - MELODY DUMAGU

We have the pleasure of introducing to you Melody Dumagu who is an MPhil student of this Department with registration number ET/HEP/21/0009.

Currently, she is at the data collection stage of her research work and we would be most grateful if you could give her the necessary assistance from your outfit to enable her progress with the collection of data.

Thank you.

Yours faithfully,

Dr. (Mrs.) Patience Danquah Monnie
HEAD OF DEPARTMENT

APPENDIX C
INTRODUCTORY LETTER FROM MUNICIPAL

In case of reply the number and date of this letter should be quoted.

My Ref. No: ***GARHD/001/2024***
Your Ref. No.

GHANA HEALTH SERVICE
Your Health-Our Concern

GHANA HEALTH SERVICE
REGIONAL HEALTH DIRECTORATE
GREATER ACCRA
P. O. BOX 184
ACCRA

Tel: +233-0302-248997

29th July, 2024

Our Core Values

- PEOPLE CENTERED
- PROFESSIONALISM
- TEAM WORK
- INNOVATION EXCELLENCE
- DISCIPLINE
- INTEGRITY

THE MUNICIPAL DIRECTOR OF HEALTH SERVICE
- GA NORTH

RE: INTRODUCTORY LETTER
- MELODY DUMAGU

Kindly find attached a letter with Reference No. VTE/IAP/V.4/63 dated 8th March, 2024 from the Head of Department, College of Education Studies Faculty of Science and Technology Education, University of Cape Coast on the above subject matter for your information and necessary support.

Thank you.

DR. (MRS.) AKOSUA AGYEIWAA OWUSU-SARPONG
REGIONAL DIRECTOR OF HEALTH SERVICE
GREATER ACCRA

Cc: Deputy Director, Clinical Care

APPENDIX D
SENSORY EVALUATION FORM

UNIVERSITY OF CAPE COAST
FACULTI OF SCIENCE
DEPARTMENT OF VOCATIONAL AND TECHICAL EDUCATION

QUESTIONNAIRE FOR SENSORY EVALUATION

Dear Respondent,

I am doing a study as part of the requirement for the award of a Master of Philosophy degree at the University Of Cape Coast. The study seeks to assess the **Nutritional Analysis of Formulated Infant Food Using Sweet Potatoes, Soybeans, and Shrimps**. I humbly invite you to partake in the study as a respondent. I will be grateful if you can respond to the items below. Your responses will be completely kept anonymous, and your name will not be associated with any part of the data. Participation in this study is not compulsory, and you are free to participate or not in the study. The information gathered will be used solely for this research work.

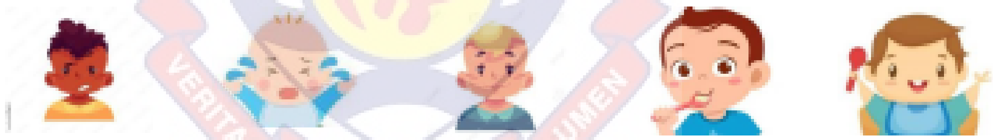
PART I: Demographic Data

1. Age of the child.......................

2. Sex: [ ] Male [ ] Female

PART II: Sensory Evaluation of Formulated Infant Food

Kindly give a little of the food to your baby to taste and rate the food depending on your baby's facial expressions. Indicate the extent to which they like or dislike each of the foods based of the foods' appearance, taste, texture, aroma, and overall acceptability using the scale below. Put the appropriate number (1, 2, 3, 4, or 5) against each attribute in the table.



Very Dislike (1) Dislike (2) Neither like nor Like moderately (3) moderately Like (4) Very Like (5))

ood samples	Appearance	Aroma	Taste	Texture	Overall acceptability
OPOSHI-Mix 1					
OPOSHI-Mix 2					
OPOSHI-Mix 3					
OPOSHI- Mix 4					
OPOSHI- Mix 5					
IFS CONTROL					

APPENDIX E
CONSENT FORM

CONSENT FORM

STUDY TITLE: Nutritional analysis of formulated infant food using sweet potatoes, soybeans, and shrimps

PARTICIPANTS' STATEMENT

I acknowledge that I have read or have had the purpose and contents of the Participants' Information Sheet read and all questions satisfactorily explained to me in a language I understand (…………..). I fully understand the contents and any potential implications as well as my right to change my mind (i.e. withdraw from the research) even after I have signed this form. I voluntarily agree to be part of this research.

Name of Participant………………………………

Participants' Signature ……………………….OR Thumb Print ……………………………

Date:…………………………………………

INTERPRETERS' STATEMENT

I interpreted the purpose and contents of the Participants' Information Sheet to the afore named participant to the best of my ability in the (……………….) language to his proper understanding. All questions, appropriate clarifications sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter……………………………………………………………………………

Signature of Interpreter ………………………..OR Thumb Print ……………………………

Date: ……………………………………………………

Contact Details……………………………………….

STATEMENT OF WITNESS

I was present when the purpose and contents of the Participant Information Sheet was read and explained satisfactorily to the participant in the language he/she understood (……………..) I