NUTRIENT COMPOSITION AND CONSUMER ACCEPTABILITY OF INSTANT COWPEA LEAF BASED SOUP

ALPHA BONIFACE SSONKO

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DECLARATION

I Ssonko Alpha Boniface, a student of Uganda Christian University pursuing a Bachelor of Science in Food Science and Technology do declare that the work in this dissertation is my original work to the best of my knowledge. The dissertation has been made based on the skills and knowledge I have acquired at the Uganda Christian University while doing the Special Project course.

Signature Date……………..11/06/2025….

Ssonko Alpha Boniface

S21B52/010

ABSTRACT

Cowpea leaves are a nutritious vegetable important in African diets, particularly in Uganda. The research indicated that their utilization is limited by post-harvest losses and nutrient loss during traditional preparation. This study aimed to enhance the sensory and nutritional attributes of an instant cowpea leaf-based soup. The research investigated the impact of incorporating additives such as monosodium glutamate, mono- and di-glycerides of fatty acids, and whey protein on the soup's physicochemical properties and consumer acceptability. The research employed the use of cowpea leaf and orange-fleshed sweet potato flour as starch-based sources, and the soup was processed using extrusion cooking. Proximate and mineral composition were analyzed according AOAC methods, and sensory evaluation determined consumer preferences. This research sought to improve the nutritional value and consumer appeal of cowpea leaf soup, to promote its consumption and address micronutrient deficiencies.

APPROVAL

This dissertation has been prepared by Ssonko Alpha Boniface under my supervision and is ready for submission to Uganda Christian University for the award of a degree of Bachelor of Science in food Science and Technology.

Signature 11/06/2025 Date…11/06/2025……………………………….

Madam Kwikiriza Mbabazize

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Contents

CHAPTER ONE

1.0 BACKGROUND

Cowpea (Vigna unguiculata) is a global vegetable whose cultivation is believed to have begun from Africa more than 5000 years ago. It belongs to kingdom (Plantae), genus (Vigna), and Species (unguiculata). Cowpea is a valuable component in the farming systems of the majority of resource poor rural households in Sub-Saharan Africa (SSA) for its various attributes. It is cultivated majorly as a vegetable as well as a cover and fodder crop. The cowpea leaves, immature pods and mature pods are an important source of micro and macro nutrients like protein, crude fibre, minerals like (calcium, iron, zinc, phosphorus), and vitamins. The tender green leaves contain 15 times more minerals, micro and macronutrients than in grains(Kizito, 2022)

Cowpea leaves are widely consumed in Africa due to their rich nutritional profile, particularly their high levels of vitamins, minerals, and dietary fiber. Cowpea leaves are consumed by up to 99.4% of households in Uganda and are often served during important occasions such as funerals, child naming ceremonies, and visits. In Uganda, cowpea is ranked third in importance, and the Kumi district in Eastern Uganda is the largest producer and consumer of the crop, with 90% of the country's production (Kizito, 2022). The consumption of cowpea as a fresh vegetable has rapidly increased in the semi-arid zone of Africa. There are no released varieties on record for vegetable use in Africa. (Kizito, 2022). However, traditional preparation methods often lead to significant nutrient loss and compromise sensory attributes such as texture, taste, and color.

A soup is a flavorful and nutritious liquid food usually served at the beginning of a meal or a snack. The flavor of the main ingredient used should remain prominent (Fern et al., 2020). Green leafy vegetables are widely used in the preparation of vegetable soups, the most common being spinach and chard. Green leafy vegetables are a good source of dietary fiber and are rich in chlorophyll, vitamins C, K, iron, and folic acid, among others. Different types of soup powders are available on the market. Most of the soup powders are usually made from combination starch-rich raw materials and mixed with different vegetables. Corn flour is used as a thickener and stabilizer agent in soups. Spices in powder form can be added to improve the palatability of soup.

An instant soup is a pre-packaged, ready-to-make soup that requires minimal preparation. Typically, it comes in powder, paste, or dehydrated form and only needs the addition of hot water (or sometimes milk) to be ready for consumption. The key Features include quick preparation usually, shelf-Stable due to dehydration or preservation techniques, convenient that is; Ideal for people looking for fast meal options. It has a variety of forms, available as powder, granules, freeze-dried ingredients, or concentrated paste.

Food additives are substances added to food to preserve flavor or enhance its taste, appearance, or other qualities and are inevitable in packaged food. The proper use of food additives plays an important role in modern food industry. Firstly, food additives not only function in food preservation, but also help to enhance certain qualities of food such as color, flavor and flexibility, as well as improving the nutrition of food. For example, proper food nutrition enhancers can be added to make up nutrition loss during food processing. Food additives have been used by man since the earliest times. The safety of food additives is an important issue related to the food industry, so the use of additives in food should be controlled by laws in many countries.(ELshreif et al., 2023)

In Uganda, where 29% of children under five are stunted (Uganda Bureau of Statistics [UBOS], 2021) and micronutrient deficiencies are prevalent, improving the nutritional quality of commonly consumed foods like cowpea leaves is essential.

This study aims to improve the sensory properties, reconstitution quality, and nutrient retention of instant cowpea leafy soup by optimizing its formulation and processing conditions.

PROBLEM STATEMENT

Despite the availability and affordability of cowpea leaves, the average dietary intake of essential vitamins and minerals remains below the recommended daily allowance, partly due to the improper preparation of these vegetables (FAO, 2020). For example, the loss of vital nutrients during cooking can reach 50% for some vitamins and minerals. Traditional preparation methods, such as overcooking and boiling without appropriate seasoning, often lead to significant nutrient losses and reduce the sensory qualities of this soup. The current practices result in the degradation of heat-sensitive nutrients like vitamin C and affect the bioavailability of minerals, thus reducing the nutritional benefits of the leafy vegetable.

The current cowpea leafy vegetable soup that was prepared by extrusion cooking, a high-temperature short-time method (HTST) targeted women of reproductive age as well as children 5 years and below to provide a healthy, easy-to-prepare dish to reduce the prevalence of nutritional deficiencies.

However, the sensory attributes do not meet consumer expectations such as texture, as the soup lumps upon reconstitution, smoothness, taste, and aroma as compared to common soups prepared traditionally. The nutritional value of the soup also does not provide the recommended daily intake of the main nutrients for the target group such as iron, zinc, folic acid, dietary fiber was all halved after analysis of the final product (Akaba et al., 2024 unpublished).

There is also a noticeable gap in research and development focused on utilizing and adding value to cowpea leaves. This neglect leaves consumers without adequate support in accessing nutritious food products derived from this valuable resource. Consequently, opportunities to address nutritional deficiencies through cowpea leaves are being missed.

To mitigate post-harvest losses and enhance the utilization of cowpea leaves, an instant cowpea soup was developed using extrusion cooking, a high-temperature short-time (HTST) processing method. While extrusion cooking offers advantages in terms of nutrient retention and microbial safety, there are still unknowns and challenges specific to its application in cowpea-based instant soups. These include:

Impact of Extrusion Parameters: The precise effects of varying extrusion parameters (e.g., temperature, screw speed, feed rate) on the nutritional composition, sensory attributes, and reconstitution properties of cowpea-based soups are not fully understood. Optimizing these parameters to maximize nutrient retention while maintaining desirable sensory qualities requires further investigation.

Ingredient Interactions During Extrusion: The interactions between cowpea leaves and other ingredients, including fortificants and additives, during the extrusion process are complex. It is unclear how these interactions affect the stability of nutrients and the overall quality of the final product.

Effect on Bioavailability: While HTST processing can help retain certain nutrients, its effect on the bioavailability of key nutrients like iron and zinc in cowpea-based soups needs further study. It is crucial to ensure that the processing method not only retains nutrients but also preserves their availability for absorption by the body.

Beyond the extrusion process itself, the current prototype of this instant cowpea leaf-based soup faces several challenges that impede its consumer acceptance and market potential. These challenges include:

Inadequate Sensory Characteristics: The soup exhibits unsatisfactory flavor, texture, and aroma, negatively impacting the overall consumption experience. Specifically, the flavor lacks depth and balance, and the color deteriorates during processing.

Poor Reconstitution Quality: The soup's texture is problematic, as it does not reconstitute properly, often resulting in lumpiness and incomplete dissolution.

Nutritional Insufficiency: The nutritional composition of the soup does not adequately meet the recommended dietary allowances, particularly for key nutrients such as zinc, iron, and protein.

These limitations, stemming from both processing and formulation issues, prevent the instant cowpea leaf-based soup from effectively addressing nutritional needs and gaining widespread consumer acceptance. Therefore, this research is necessary to investigate ingredient enhancements and processing modifications, with a focus on optimizing the extrusion process, to improve the soup's sensory qualities, nutritional value, consumer appeal, and usability. This initiative will involve fortifying the soup and incorporating stabilizers and emulsifiers to enhance its texture, stability, and shelf life. For example, monosodium glutamate will be explored for its potential to enhance umami flavor and allow for sodium reduction, a mixture of mono- and diglycerides of fatty acids will be used to improve reconstitution and prevent phase separation, and whey protein will be added to improve creaminess, mouthfeel, and protein content.

Therefore, this research aimed at improving the nutritional (iron, zinc and folic acid) and sensory quality (smoothness) of the product to enhance its acceptability and consumption.

1.2 RESEARCH OBJECTIVES

1.2.1 Main Objective:

To determine the contribution of selected enhancers to the sensory and nutritional attributes of the instant cowpea leaf-based soup.

Specific objectives

1.To determine the physicochemical characteristics of the instant cowpea leaf-based soup across the three treatment groups.

2. To determine the consumer acceptability of the instant cowpea leaf-based soup across the three treatment groups.

1.2.2 RESEARCH QUESTIONS

1.What are the physicochemical characteristics of the instant cowpea leaf-based soup across the three treatment groups?

2.What is the consumer acceptability of the instant cowpea leaf-based soup across the three treatment groups?

1.3 JUSTIFICATION

Uganda has a high prevalence of micronutrient deficiencies, particularly among children and women of reproductive age. The study seeks to improve the bioavailability of Vitamin A, iron, zinc, and folic acid in an instant cowpea leafy soup, addressing critical nutritional gaps. In developing countries, especially African countries, malnutrition remains a major health problem in infants and pre- school children.(Olapade et al., 2012)

High Post-Harvest Losses affecting cowpea leaves, despite their nutritional value, have a short shelf life, leading to significant post-harvest losses of 10-50%. Developing an instant soup will enhance preservation, reduce wastage, and increase utilization.

Limited Research on Cowpea Leaves for Instant Soup. While cowpea leaves are widely consumed in Africa, there is limited research on their use in processed food products like instant soup. This study will provide insights into optimizing processing techniques for better retention of nutrients and sensory attributes.

Consumer Acceptability Issues. Previous formulations of instant cowpea soup faced challenges in texture, flavor, and reconstitution quality, leading to low consumer acceptance. This study aims to enhance these properties by incorporating functional additives.

Market Potential and Convenience. The demand for instant, easy-to-prepare, and nutrient-dense foods is increasing. This research aims to develop a shelf-stable, highly nutritious soup product that meets consumer needs for convenience and health benefits.

Meeting the Demand for Convenient and Nutritious Foods: There is a growing demand for convenient, easy-to-prepare, and nutrient-dense food products. This research aligns with this market trend by developing a shelf-stable, highly nutritious soup that meets consumer needs for convenience and health benefits. Such a product has the potential to address both nutritional deficiencies and consumer preferences in a rapidly changing food environment

1.4 SIGNIFICANCE

Improved Nutritional Intake. By enhancing the bioavailability of iron, zinc, and folic acid, the study contributes to reducing malnutrition and anemia among vulnerable populations.

Iron regulates several biochemical processes such as electron transfer reactions, gene regulation, binding and transport of oxygen, and regulation of cell growth and differentiation. Its deficiency contributes to anemia. It is essential for fetal growth and development, and thus iron demand is high during pregnancy and any shortage onsets the intrauterine growth restriction, premature delivery, low birth weight and postpartum depression, to name a few. South Asia and Sub-Saharan Africa account for the highest anemia prevalence in pregnant women and pre-school children of 47.7 and 55.1 %, and 45.8 and 59.9%, respectively(Janaswamy et al., 2021)

Enhanced Shelf Life and Marketability. The development of a stable, fortified soup product will extend the usability of cowpea leaves and create economic opportunities for farmers and food processors.

Better Sensory and Functional Properties. The study will optimize the soup's formulation to improve texture, flavor, and overall acceptability, increasing its potential for commercialization.

Contribution to Food Security and Value Addition. The research supports food security by promoting the use of underutilized but nutrient-rich vegetables. It also adds value to agricultural produce, supporting rural livelihoods.

Scientific Contribution. The findings will provide data on optimizing processing techniques for cowpea leaf-based products, potentially influencing future food formulation and processing strategies.

1.5 CONCEPTUAL FRAMEWORK

Independent Variables: These are the factors you are manipulating or changing in your experiment.

Types and levels of additives: Caramel (for color), Whey protein isolate, MSG (Monosodium glutamate)

Point of additive addition: Pre-extrusion or Post-extrusion

Extrusion Cooking Parameters

Temperature

Screw speed

Dependent Variables: These are the outcomes being measured to determine if they are affected by the independent variables.

Physicochemical Characteristics of the Soup:

Proximate composition (dry matter, ash, crude protein)

Mineral content (Zinc, Iron, Calcium)

Viscosity (related to texture)

Sensory Attributes of the Soup: Appearance, Color, Aroma, Flavor, Taste, Texture/Mouthfeel and Overall acceptability.

Control Variables: These are factors that you keep constant to ensure that only the independent variables are affecting the dependent variables.

Base ingredients (cowpea leaf powder, OFSP flour, maize flour)

Extruder type

Basic extrusion process

Cooking procedure of soup powders

Panelists (sampling is used to control this)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Cowpea production worldwide and in Uganda

Cowpea, Vigna unguiculata (L.) is the most important legume grown in the semi-arid tropics and one of the world's major legumes. It is adapted to the Sahelian climate which is characterized by low rainfall and poor soil fertility. It originated and was first domesticated in Southern Africa and was later moved to East and West Africa and Asia. It is a multi-purpose indigenous crop that grows largely in the tropics of sub-Saharan Africa (SSA). It is reported that 95.6% of the area under cultivation of cowpea leaves worldwide in 2017 was in Sub Saharan Africa. Uganda is ranked the 8th largest producer of cowpea in Africa, grown by over 2.2 million smallholder farmers with total annual production of nearly 22,000 tons. Cowpea in Uganda is grown throughout the country but Eastern and Northern region being the 1st and 2nd largest producers in the country.(Pokhrel, 2024)

2.2 Nutritional Significance of Cowpea Leaves

Cowpea leaves are an excellent source of vitamins A, C, and K, minerals like iron and calcium, and dietary fiber. Their high antioxidant content provides health benefits such as improved immunity and reduced oxidative stress. However, improper processing can lead to significant nutrient losses, necessitating optimized cooking and formulation strategies to retain their full nutritional potential.

Cowpea leaves possess a rich nutritional profile, serving as a crucial reservoir of essential nutrients such as proteins, vitamins, and minerals. Cowpea leaves possess significant levels of carotenoids, including lutein, violaxanthin, α-carotene, 9-cis-ß-carotene, and zeaxanthin. They contain a considerable amount of phytochemicals such as flavonoids and phenolic acids. These leaves are also characterized by their low-fat content and significant contribution to dietary fibre intake(Mungofa & Beswa, 2024)

Consumption of cowpea leaves improves the activity of both micro and macro-nutrients in the human body by preventing iron and protein-calorie deficiencies (Pottorff et al., 2012; Alemu et al., 2016). Organoleptically, cowpea leaves are mild and good tasting compared favorably with other tropical vegetables like amaranth, spinach, pumpkins, lettuce, and sweet potatoes (Mamiro et al., 2011). Cowpea leaves also compare well nutritionally with other tropical leaf vegetables like Solanum nigrum, Amaranthus sp., Ipomoea batatas, and Cucurbita moschata (Gonçalves et al., 2016). Cowpea leafy vegetables can increase the nutrient content of less nutrient-dense foods due to their significantly high nutrient content (Wasswa, 2021). A study by Prange (2012) reported that with an increase in age, cowpea leaves indicated an increase in carbohydrates, and a reduction in their protein content while maintaining a consistent level of fat and ash content. Cowpea leaves are priced lower than animal protein Devi (2020) and possess a higher protein content than seeds during the cropping season, with protein percentages ranging from 24.7% to 25.7% for seeds and 29.4% to 33.1% for leaves (Prange, 2012). A study by Mamiro et al. (2011) found that cowpea leaves produce 9 times as many calories, 1.5 times as much protein, 90 times more calcium, and 1,000 times more ascorbic acid and beta carotene than the crop's grains.

Cowpea is a rich source of proteins (28-42 g/100 g), total essential amino acids (0.027-0.031 mg/100g), crude fiber (10.09-25g/100g), carotenoids (32.74-36.55mg/100g), iron (66-75 mg/100g), calcium (17.1-39.87 mg/100 g) and, zinc (5.22-12.91mg/100g). According to Carneiro da Silva et al. (2018), cowpea is a significant dietary protein source that nutritionally complements low-protein cereal and tuber crops and is extremely important to millions of people in developing nations, estimated 38 million families, or 194 million individuals (Davis et al., 2007; Owade et al., 2019). Larochelle et al. (2013) showed that cowpea crude protein concentrations of 561 cowpea leaf samples taken from 10 accessions and around 10 landraces in Tanzania and Uganda ranged from 21.5% to 40.3%.

Cowpea leaves contain vitamins and minerals, that are uncommon in most exotic plants, and consuming AIVs helps poor rural households combat malnutrition (Ojiako & Kayode, 2014; Okello et al., 2015; Osho & Olasanmi, 2019; Omomowo & Babalola, 2021). Leafy cowpea contain trace amounts of zinc, copper, manganese, sodium, iron, and selenium (Hamid et al., 2015). A study by Kim et al. (2014), reported that the mineral content of various cowpea cultivars varied greatly. Okonya (2014), showed that young cowpea obtained from Tanzania and Uganda had carotene values ranging from 4.1 to 30.5 mg/100 g and iron concentrations ranging from 140.5 to 3994.7 g/100g. In comparison to cooked cowpea seeds, cooked cowpea leaves have a calcium content that is seven times higher, an iron content that is three times higher, and the phosphorus concentration of cooked cowpea leaves is equivalent to 50% of that found in cooked seeds.

Cowpea is rich in essential vitamins like B vitamins (B6 &B9), riboflavin, thiamin, niacin, and pantothenic acid, as well as β - Carotene, Ascorbic acid (Asare et al., 2013; Ngalamu et al., 2014). The amount of readily available nutrients, such as vitamin C, in leafy cowpea, is decreased by sun-drying before cooking, adding crude sodium carbonate salt to the cooking water, and heating them for an extended period (Gonçalves et al., 2016). Also, Okonya, (2014), reported that children who ate cowpea leaves had higher blood hemoglobin levels and more bioavailable beta-carotene. Vitamins C and E are crucial for women of reproductive age because they function as antioxidants, which are substances that disarm free radicals and shield cells and tissues from oxidative deterioration (Otunchieva et al., 2022). When comparing raw cowpea seeds to raw cowpea leaves (not dried), the cowpea leaves contain around 20% more thiamine and twice as much riboflavin. Similar to cowpea seeds, cowpea leaves are a highly valuable reservoir of folic acid, with quantities of 334 µg and 2012 µg of free and total folate per 100 g of solids in their raw form (B.B. Singh, 1997).

2.3 Post-harvest handling of cowpea leaves

Role of Orange Flesh Sweet Potato (OFSP) Flour

OFSP flour is rich in beta-carotene, which enhances vitamin A intake, a critical nutrient for vision and immune health. It also improves the texture and color of food products, making it an ideal ingredient for fortifying cowpea soup while enhancing its sensory appeal.

Sweet potato (Ipomoea batatas) is of great nutritional and health significance, mainly due to its beta-carotene and anthocyanin properties(Omoba et al., 2020)

Importance of Functional Additives in Food Processing

Additives play a crucial role in food formulation by enhancing flavor, texture, and stability. The following additives are particularly relevant to this study:

Monosodium Glutamate (MSG): Commonly used to enhance umami flavor, MSG improves overall taste perception and consumer acceptance. Commercially prepared soup mixes are usually made using (MSG) Monosodium Glutamate to enhance desired flavor. MSG restores some of the original flavors, increases palatability and raises overall flavor level while reducing sodium chloride concentration (Abeysinghe & Illeperuma, 2006)

Mono- and Di-Glycerides of Fatty Acids: These emulsifiers help improve texture by preventing phase separation and ensuring smooth consistency.

Whey Protein: Enhances the mouthfeel and protein content of the soup, making it more nutritious and appealing.

Caramel: Caramel, defined as coloring agent and as an anti- oxidant, is being used in several kinds of food products.(Sengar & Sharma, 2014) Used for color enhancement, caramel provides an appealing golden-brown hue, improving the visual acceptability of the soup.

2.4 Impact of Processing on Nutrient Retention

High-temperature, short-time (HTST) processing techniques such as extrusion cooking help retain heat-sensitive nutrients like vitamin C while ensuring microbial safety. This method minimizes nutrient loss while maintaining a desirable texture and consistency in instant soups.

2.5 Consumer Acceptability and Market Trends

Consumer panels are composed of individuals from the target market, providing feedback that reflects real-world consumer preferences. This type of panel is crucial in consumer acceptance studies, which aim to predict market success based on consumer reactions to sensory attributes (Maurya, 2024).

Consumer studies indicate that texture, flavor, and ease of preparation significantly influence the acceptability of instant soup products. Research suggests that the incorporation of nutrient-dense ingredients and functional additives enhances overall consumer satisfaction and repeat purchases.

For biofortification to be effective, it must align with consumer preferences. Studies underscore the importance of sensory evaluation in determining the acceptability of biofortified products (Mbwana et al., 2021). In regions where cowpea is not traditionally used in soups, its integration must consider local culinary practices and taste preferences.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Raw materials

Ingredient Selection and Formulation

Base Ingredients: Cowpea leaf powder, Orange Flesh Sweet Potato (OFSP) flour, maize flour, and selected spices.

Functional Additives: MSG, Mono- and Di-Glycerides of Fatty Acids, Whey Protein, and Caramel were purchased from suppliers around Kampala and Nairobi

Fortificants: to improve iron and zinc bioavailability were purchased from suppliers around Kampala such as Wami Quality Chemicals, Wandegeya.

3.2 Preparation of cowpea leaves grits.

Fresh cowpea leaves were plucked and washed with clean running water. The water was drained, and cowpea leaves were blanched and dried in an air-conventional dryer at 65°C for 6 hours at the National Agricultural Research Laboratories Kawanda FBA Incubation Centre. After drying, the pieces were allowed to cool and milled into powder and stored a in polythene packet at room temperature.

3.3 Preparation of orange-fleshed sweet potato (OFSP) flour

OFSP tubers were washed with clean water to remove soil and dirt, peeled using a kitchen knife, chopped to about 0.2-0.4 cm width, 2-5 cm length, and 0.1-0.3 cm thick, and dried in an air conventional dryer at 65˚C for 48 h. The dried chips were milled into powder to pass through a 0.5 mm mesh screen and then stored in a polythene packet at room temperature.

Formulation	Composition	Processing	
A (Control)	7% cowpea, 46.5% OFSP, 46.5% maize	Extrusion at 180°C	
B (Modified)	A + 2% caramel, 1.5% calcium carbonate	Co-extrusion	
A07	B + 5% whey protein isolate	Post-extrusion addition	

3.4 Extrusion Cooking Technology

The formulations were extruded using a single screw extruder at Food Bioscience and Agribusiness incubation center powered by a 7.5 HP motor (Model So sejin). The extruder's barrel had a diameter of 19 mm, and after the feeding section, the barrel temperature was maintained at 150ºC. The extruder was operated at a temperature of 180ºC, the main screw speed of 1450 rpm, and the knife motor speed of 150 rpm, and the cooked product was forced through a round-shaped die. The cooking temperatures were controlled using an automatic cooler and monitored using an infrared thermometer. When the die pressure and screw speed were constant, extrudates emerging from the die were collected and allowed to stand for 30 minutes on a cooling conveyor to aid sufficient cooling. The cool extrudates were then milled in a hammer mill, and mounted with a 0.5 mm screen to obtain the instant flour. The instant flour was packaged into sealed plastic HDPE Ziploc bags and stored at ambient temperature, in a cool dry place.

3.5 Proximate Composition

The proximate composition including dry matter, ash content, crude protein of the instant soup was determined according to the Association of Official Analytical Chemists (AOAC), (2005). The results were presented as an average of duplicate determinations. The protein content (CP) was determined by protocol Adopted from AOAC Method 978.02, 16th Ed. Using the Kjeldahl apparatus, A factor of 6.25 was used to convert from total nitrogen to CP (%).Dry matter was determined by oven drying method 925.10 (AOAC, 2005)

3.6 Mineral composition (Zinc, Iron, Calcium)

The mineral content of samples was determined according to Schroeder et al. (2015), using a Bruker S1 TURBO hand-held XRF analyzer with a silicon drift detector that operated at 45 kV and 30 mA, with a Ti/Al filter. The XRF spectrometer was controlled via a Hewlett Packard PDA using XBruker Elemental S1 software with a resolution was approximately 145 eV at 200,000 cps. Three SRM samples (0.80 g/sample) were analyzed thrice each for 30 seconds. The sample cup was put on a safety platform mounted to the instrument's tip to guarantee equal distance for analysis. The data obtained was in parts per million (PPM).

3.7 Sensory Evaluation

A panel of 60 untrained panelist with an average age of 20 ± 8.2 was evaluate the samples based on flavor, texture, color, and overall acceptability using a descriptive analysis or hedonic scale.

Purposive sampling was employed as the sampling approach, and panelists were chosen based on their availability, willingness to participate, and consumption of cowpea vegetables. The samples were distributed to the panelists using a research randomizer, which distributes the treatments among the panelists so that each is repeated the same number of times, and each treatment appears precisely once in each row and column in the design, reducing Systemic error. A complete randomized design (CRD) was applied that indicated samples were distributed to the panelists randomly.

Panelists were asked to provide their honest judgments after tasting the instant cowpea leaves based product. Each participant was asked verbally to agree to participate and to disclose any allergies they might have to any of the processed food items.

3.8 Cooking procedures of soup powders and Consumer Acceptability Tests

The instant soup was prepared using 200 grams of instant cowpea soup and salt (2g) then added into 1500 ml hot water and boiled for 5 min (to pasteurize) ready for evaluation. Appearance, color, aroma, flavor, texture (mouth feel), taste, and overall acceptability of the sensory qualities were assessed using a 9-point Hedonic scale, (1= "I extremely dislike it" and 9 being "I enjoy it extremely"). The following items were given to each panelist: serviettes, 5 samples of the instant soup, and water to rinse the palate before and after testing the samples. The test used 200 ml disposable white cups containing 40–50 ml of instant soup. Sensory evaluation was conducted in sensory booths that separated the panelists; one sample was given to the panelists at a time. The different samples were assigned three-digit codes.

Statistical Analysis

All data collected from the survey was expressed as means and standard deviation (SD) for the individual nutrient. All the nutritional and sensory analyses were performed in triplicate, and data were analyzed using EXCELSTAT version

2012.10.7.01 Addinsoft, Paris France). The statistically significant difference was stated at $p < 0.05$.

CHAPTER FOUR

4.0 RESULTS

Table 1: Mineral Content by Treatment Type

Mineral	Treatment A	Treatment B
P (mg/kg)	1713.00 ± 156.81	1713.67 ± 83.80
K (%)	1.41 ± 0.11	1.24 ± 0.13
Ca (mg/kg)	3942.33 ± 342.96	4280.33 ± 476.91
Mg (mg/kg)	6100.00 ± 458.26	6433.33 ± 965.02
S (mg/kg)	2011.67 ± 141.80	1805.33 ± 222.72
Fe (mg/kg)	744.67 ± 436.03	532.33 ± 343.93
Zn (mg/kg)	86.33 ± 95.33	202.33 ± 20.84
Cu (mg/kg)	14.33 ± 7.77	11.00 ± 7.55

Table 2: A table showing consumer acceptability scores by means and standard deviations for each Treatment Group.

Treatment Group	Appearance	Colour	Aroma	Flavor	Taste	Mouthfeel	General Acceptability
A07(Base+ additives) +whey protein (post extrusion)	$5.94^{a} \pm 2.14$	$5.98^{a} \pm 2.25$	$5.74^{a} \pm 2.34$	$5.87^{a} \pm 2.36$	$5.78^{a} \pm 2.33$	$5.41^{a} \pm 2.20$	$5.89^{a} \pm 1.93$
A (Base ingredients without additives)	$6.20^{a} \pm 2.20$	$5.91^{a} \pm 2.18$	$6.27^{a} \pm 1.97$	$6.11^{a} \pm 1.94$	$5.80^{a} \pm 2.15$	$5.79^{a} \pm 1.96$	$6.23^{a} \pm 1.80$
B (Base + additives added pre-extrusion)	$6.45^{a} \pm 2.12$	$6.26^{a} \pm 2.00$	$6.35^{a} \pm 2.10$	$6.01^{a} \pm 2.01$	$5.94^{a} \pm 2.21$	$5.85^{a} \pm 2.05$	$6.26^{a} \pm 1.91$

No statistically significant differences were found between treatment groups for any parameter ($p > 0.05$)

Table 3. A table showing proximate composition across the treatment groups

	A	B	A07
protein(%)	$29.450^{a} \pm 1.187$	$52.294^{b} \pm 2.815$	$65.795^{c} \pm 2.596$
moisture(%)	$4.421^{a} \pm 0.396$	$4.131^{a} \pm 0.168$	$4.138^{a} \pm 0.422$

CHAPTER FIVE

5.0 Discussion of Results

Table 1.

There were no statistically significant differences found for any of the minerals (all p-values > 0.05).

Treatment B had higher Calcium, Magnesium, and Zinc levels while treatment A had higher Potassium, Sulfur, Iron, and Copper levels.

The zinc content in Sample B was notably higher, though not statistically significant ($p = 0.107$) which was attributed to the fortificant used. However, the levels of fortificants were not high enough to create a significant difference due to maximum levels allowed according to US_EAS_786_2019 standard

Table 2.

The B samples generally had the highest mean scores across most sensory attributes.

The A07 sample consistently had the lowest scores, especially in mouthfeel (5.41) and aroma (5.74) which indicates a slight preference for fortified samples and other A samples over A07.

The high standard deviations across all groups indicate wide variation in individual responses, making it harder to detect significant differences.

No statistically significant differences were found between treatment groups for any sensory attribute ($p > 0.05$). While fortified samples (B) scored slightly higher, the differences were not strong enough to be considered meaningful statistically.

The color of the soup is not ideally representative of common soups on the market. Cowpea leaf powder was common to these two soup formulations and so contained chlorophyll pigments that imparted a dark green color to the soup, and the intensity of the green color increased as the concentration of composite mixes increased in the formulations to 10% and then 15%(Mungofa & Beswa, 2024)

Table 3

Group A (Base Treatment):

Minimal processing and no protein additives were used thus lower protein suggests no whey fortification.

Group B (Additives Pre-Extrusion):

This contained whey protein, MSG, colorants, and fortificants added before extrusion.

During extrusion, whey protein was exposed to high heat (120–185°C), causing partial denaturation and reduced solubility thus may explain the moderate protein retention compared to A07.

Group A07 (Additives Post-Extrusion):

Whey protein was added after extrusion, avoiding heat-induced denaturation. This preserved protein integrity and functionality, leading to higher measurable protein content. Whey protein is highly sensitive to heat, especially during extrusion: Denaturation: At temperatures above 70°C, whey proteins (e.g., β-lactoglobulin) unfold, losing solubility and forming gels.

Extrusion Challenges: Pre-extrusion whey addition (Group B) risks over-browning, dense texture, and reduced solubility due to prolonged heat exposure.

Post-Extrusion Advantage: Adding whey post-extrusion (A07) bypasses these issues, preserving protein quality and boosting measurable content.

Moisture Stability

All groups show similar moisture levels (~4.1–4.4%).

Extrusion parameters (e.g., controlled water flow) and formula adjustments likely stabilized moisture, preventing fungal/bacterial growth.

5.1 Conclusions.

The use of selected additives did not serve the purpose of improving the soup quality. For biofortification to be effective, it must align with consumer preferences. Studies underscore the importance of sensory evaluation in determining the acceptability of biofortified products (Mbwana et al., 2021).

5.2 Recommendations.

Investigate the use of additives at higher levels according to good manufacturing practices (GMPs) to enhance sensory characteristics further in B samples to create a clearer distinction.

The use of a larger sample size or a more focused sensory panel (e.g., trained panelists) to reduce variability and detect precise differences.

The additives may be beneficial, but their levels need to be optimized to determine the levels that give the best outcome. This should be coupled with a cost benefit analysis to ensure benefits outweigh costs.

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APPENDIX

Table *1.1*: Nutritional composition of cowpea leaves and mature seeds (100g edible portions).

Part	Leafy			Seed	
	Raw	Leaf Dried	Cooked	Raw	Cooked
Protein	4.7	22.6	3.2	22.8	5.1
carbohydrate	8.3	54.6	na	61.7	13.8
fat	0.3	3.2	0.3	1.5	0.3
Ca(mg)	256	1556	132	74	17
P (mg)	63	348	41	426	95
Fe (mg)	5.7	12	4.7	5.8	1.3

Source: Singh, B. B. (1997). Advances in Cowpea research. IITA.

Table 2 Anova table for protein

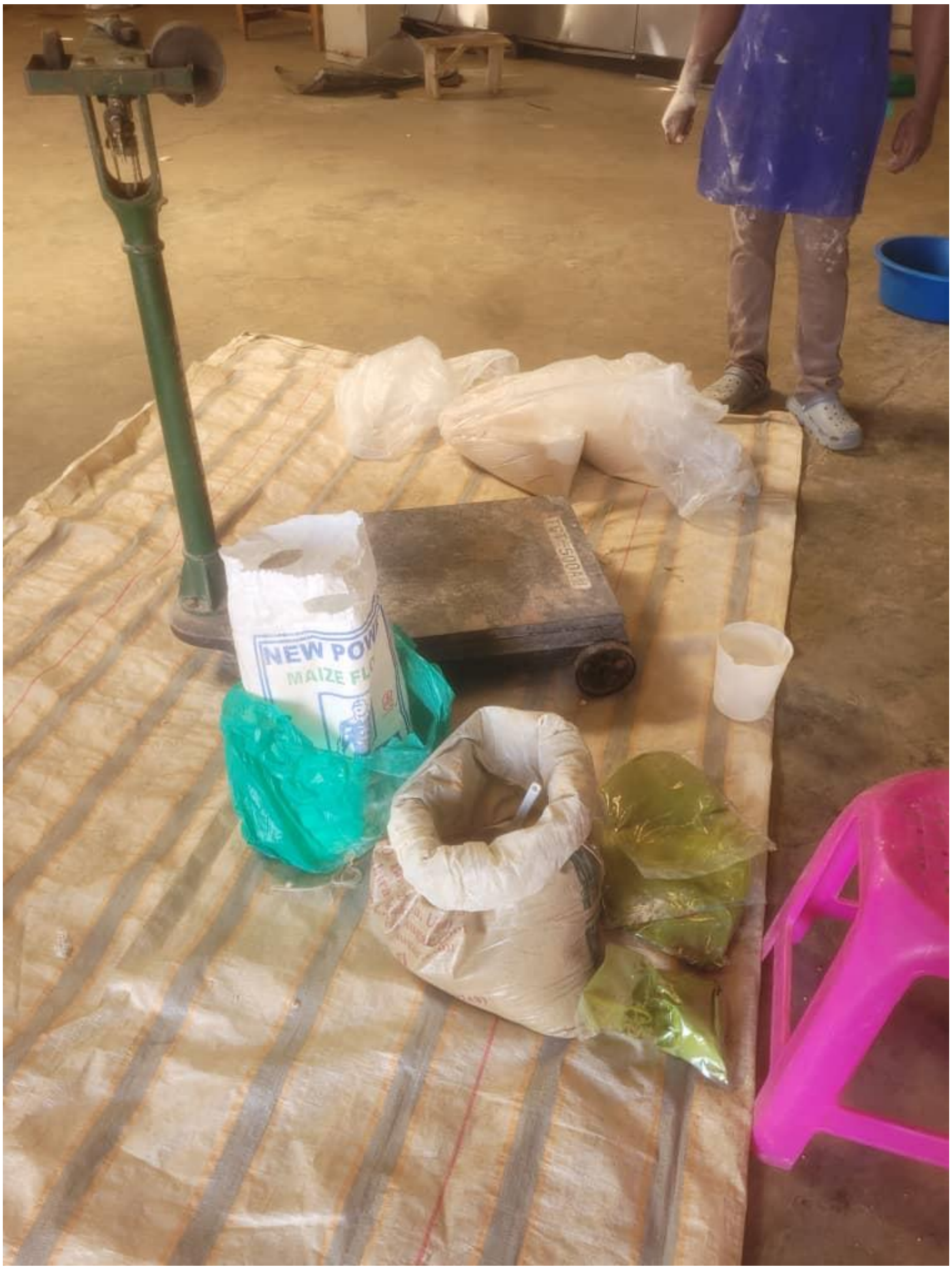
Source	SS	df	MS	F	p-value
Between Groups	2025.157	2	1012.579	126.001	< 0.0001
Within Groups	48.218	6	8.036		
Total	2073.375	8			

Table 3 Anova table for moisture content.

Source	SS	df	MS	F	p-value
Between Groups	2	0.165	0.082	0.454	> 0.05
Within Groups	6	1.089	0.181		
Total	8	1.253			

Table 4 t-table for mineral analysis

mineral	Group A Mean	Group A SD	Group B Mean	Group B SD	t-statistic	p-value	Significant?
P	1707	153.27	1713.67	83.91	-0.0661	> 0.10	No
K	1.41	0.11	1.24	0.13	1.7639	< 0.10	Yes (α=0.10)
Ca	3942.33	340.23	4280.33	482.49	-0.9916	> 0.10	No
Mg	6100	458.26	6433.33	960.9	-0.5423	> 0.10	No
S	2011.67	141.99	1805.33	223.67	1.349	> 0.10	No
Fe	744.67	436.21	532.33	347.72	0.6593	> 0.10	No
Zn	77.33	79.43	202.33	20.74	-2.6374	< 0.05	Yes (α=0.05
Cu	14.33	7.77	11	7.55	0.533	> 0.10	No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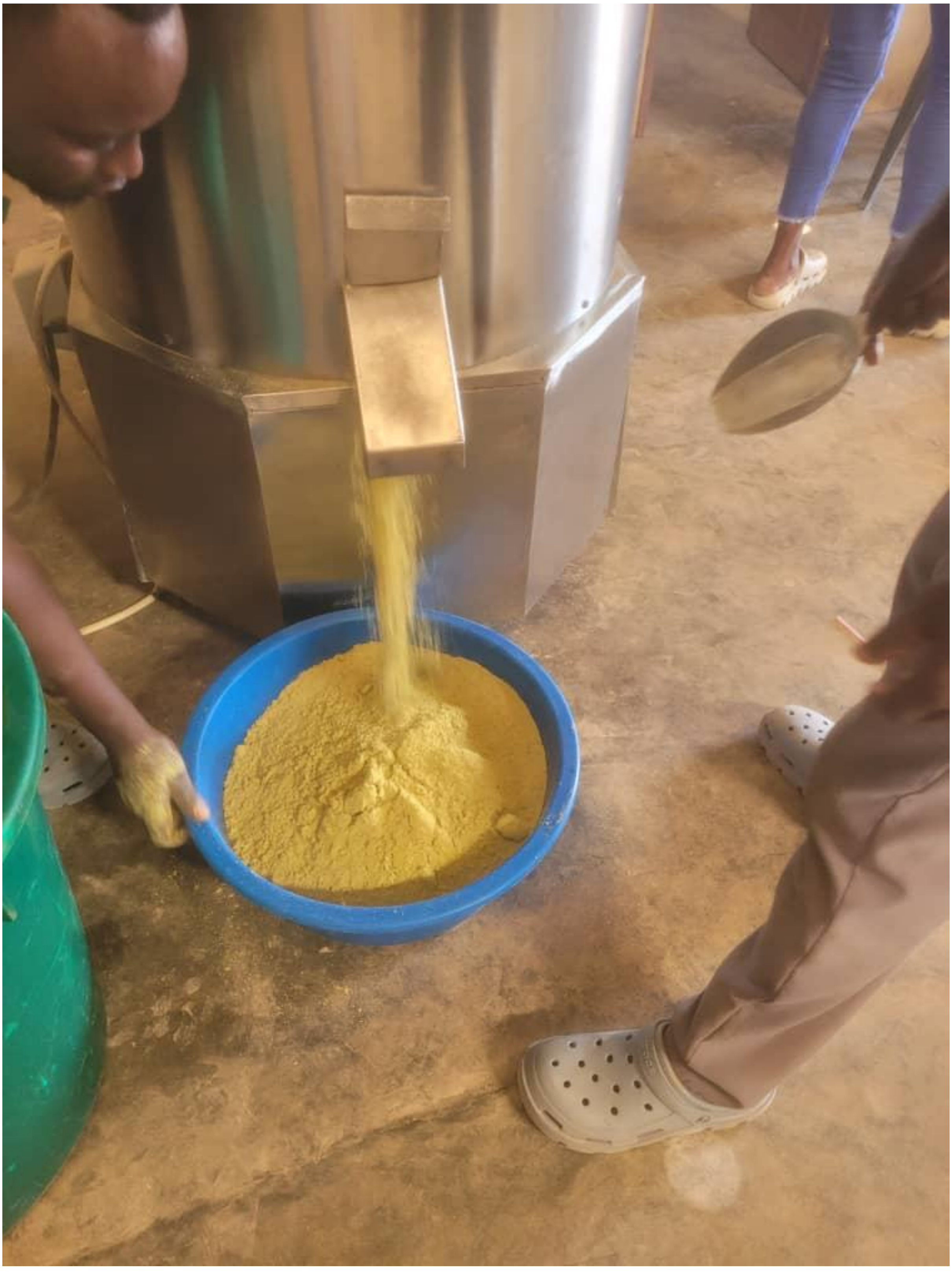

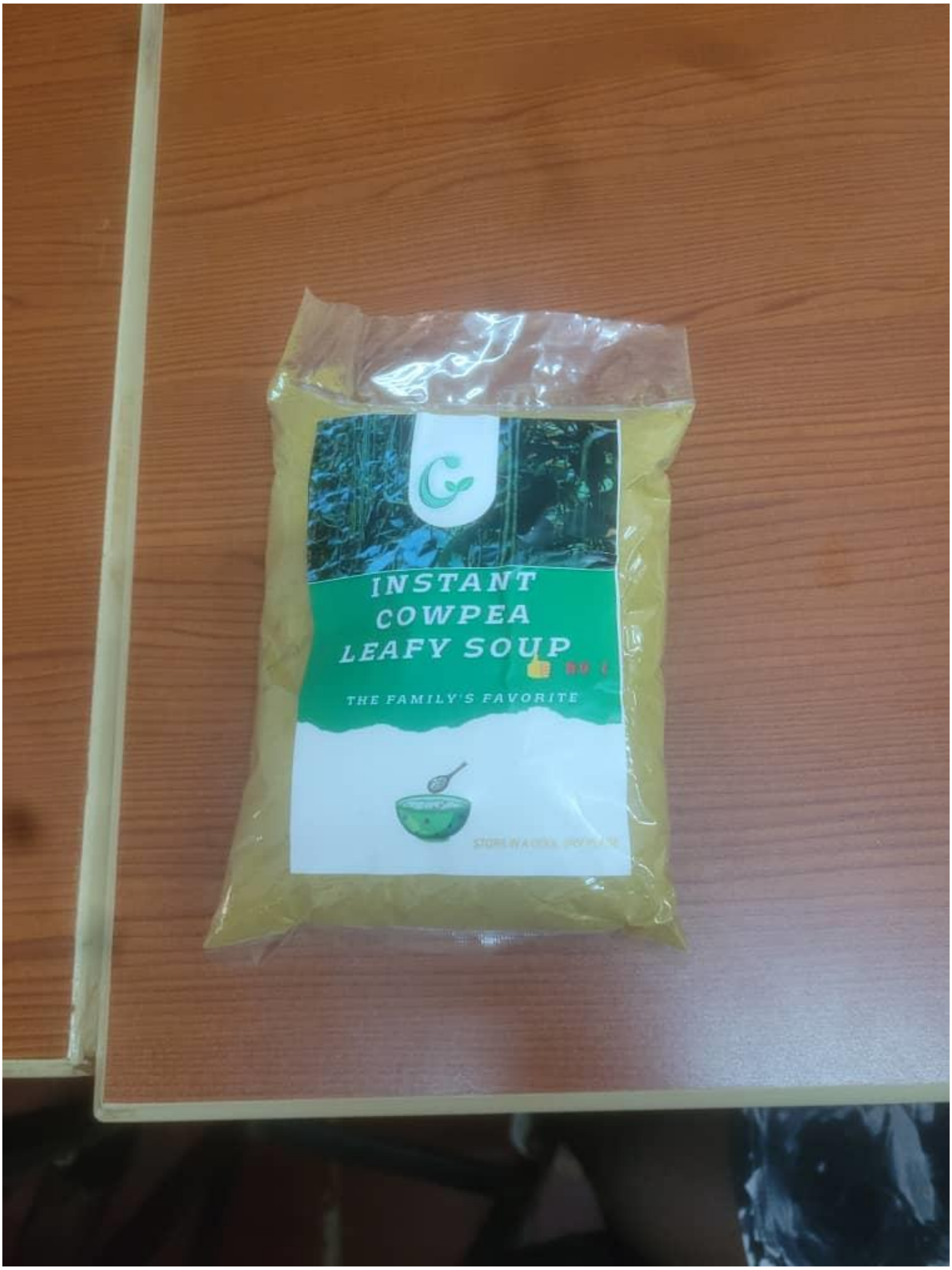
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COWPEA
LEAFY SOUP
THE FAMILY'S FAVORITE