Nutritional and Sensory Evaluation of Instant Extruded Snack Developed from Blends of Malted (Yellow Maize and White Sorghum), Soybeans, Sweet Potato and Brisket Bones

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Certification

This is to certify that **Samuel Olusina OWOLABI** with matric no. **LCU/PG/002706,** Carried out this Thesis titled Nutritional and Sensory Evaluation of Instant Extruded Snack Developed from Blends of Malted (Yellow Maize and White Sorghum), Soybeans, Sweet Potato and brisket Bones under my supervision in the department of Human Nutrition & Dietetics, Faculty of Basic Medical & Applied Sciences for the award of Master of Science Degree in Human Nutrition and Dietetics and that this has not been previously submitted

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Dedication

This research is dedicated to the glory of Jesus Christ, the Alpha and the Omega.

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Even though the institutions and persons mentioned above have assisted in the process of this research I alone take the responsibility for any error if found in this research work

Abstract

This study evaluated the nutritional and sensory properties of instant extruded snacks from a combination of malted yellow maize and white sorghum, soybean, sweet potato, and brisket bones. The maize and sorghum were malted for 30 and 20 hours respectively, while the sweet potatoes, soyabean and brisket bones were dried and converted to flours. Nine flour blends were formulated and subdivided into three segments where Segment A (maize based),ASO BSO: & CSO, Segment B (sorghum based),DSO, ESO , FSO. and Segment C (maize-sorghum based), GSO, HSO, ISO, were used to produce instant extruded snacks using a twin-screw extruder. The proximate and nutritional properties of the extrudes were evaluated, sensory evaluation was conducted using a 9-point hedonic scale, and the results were analyzed using SPSS. The analytical values for the nine samples ranged from 3.10 to 3.20% for moisture content, 1.71 to 2.00% for ash, 10.29 to 10.58% for fiber, 12.80 to 14.52% for crude protein, 3.10 to 3.15% for fat, 66.08 to 68.33% for carbohydrate, and 350.27 to 355.94 kcal for energy. Micronutrient values per 100mg ranged from 260.23 to 275.10mg for calcium, 137.22 to 162.42mg for magnesium, 455.23 to 458.35mg for potassium, 120.00 to 142.45mg for sodium, 370.23 to 403.23mg for potassium, 40.20 to 49.65mg for iron, 2.21 to 3.23mg for zinc, 3.43 to 4.56mg for vitamin A, 3.76 to 4.34mg for vitamin B1, and 0.69 to 0.76mg for vitamin B2. The results showed no significant differences ($p>0.05$) between samples from the same cereal base, but significant differences ($p>0.05$) between samples from different cereal bases. Increasing soybeans and malted grains increased the protein and carbohydrate content. Conclusively, maize-based formulations were preferred over sorghum-based. Nutritional, healthy, and acceptable instant snacks for managing malnutrition can be developed from these snacks.

Keywords: Instant extruded snacks, Malted yellow maize, Soybeans, Sweet potatoes, Brisket Bone.

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Chapter One

1.0 Introduction

1.1 Background to the Study

In recent decades, snacking has become more prominent, particularly among children[17]. Snacks are classified as convenience foods that are useful adjuncts to regular meals and constitute an important part of many consumers' daily nutrient and energy intakes[2]. Snacks can contribute significantly to a child's dietary intake, so it's important to make sure they're healthy and nourishing[17]. Protein-energy malnutrition and micronutrient deficiencies are the two main nutritional problems that characterize malnutrition in many developing nations, including Nigeria[4]. The high cost and inadequate production of protein-rich foods have resulted in increased protein-energy malnutrition among vulnerable groups due to insufficient intake of energy, protein, and micronutrients which predisposes them to endemic-related diseases such as kwashiorkor, marasmus and noma (Cancrumoris[21].

Over-reliance on readily available carbohydrate-based foods and the almost complete lack of ready-to-eat cereal-legume blends exacerbate the problem, as even when they are, they could be out of reach for the bulk of the population. To significantly contribute to providing the necessary dietary requirements to ease the obstacles, ready-to-eat snacks rich in protein must be made from inexpensive, locally sourced raw materials[19].

Ready-to-eat (RTE) foods are foods which have been processed and can be safely consumed without any further preparation or heat treatment, some of which include snacks[7]. Ready-to-eat snacks are becoming more and more popular among consumers, mostly because they are convenient to prepare and store, easy to consume, and have appealing qualities like texture, affordability, convenience, and appearance[13,8]

Most ready-to-eat (RTE) snacks may be grouped into different categories: flaked cereals (corn flakes, wheat flakes, and rice flakes), including extruded flakes, gun-puffed whole grains, granola cereals, compressed flake biscuits, extruded and other shredded cereals, oven-puffed cereals, extruded gun-puffed cereals, extruded expanded cereals, baked cereals, compressed flake biscuits, and filled bite-size shredded wheat[10].

Extruded snacks such as breakfast cereals, cereal shapes, and cereal biscuits/bars, have historically dominated this market. Most of these cereal RTE were made from whole grains and were mostly flaked from steamed grains, which allowed the grains to reform throughout the flaking process because of the steam. In a similar vein, eating snacks made of extruded materials such as expanded and pellet forms is growing in popularity among customers who are health-conscious.[6]

Cereals are the preferred and most common raw materials for manufacturing of snacks due to their practical qualities, low cost, and ready availability.[11] Pulses and oilseeds can be added to boost the nutritional value of cereal-based extruded snack meals due to their high nutrient content, especially protein.[3] Other ingredients can be added to improve texture and palatability during the extrusion process.

Sorghum (Sorghum bicolor) is one of the most underutilized crops in the semi-arid tropics of Asia and Africa. It is the principal source of energy, protein, vitamins and minerals for millions of the poorest in these regions.[12] Sorghum products are deficient in essential amino acids such as lysine, methionine, tryptophan and the presence of anti-nutritional factors such as tannins and phytates limit their nutritional value[12]. Sorghum has some limitations, due to the presence of anti-nutritional factors, such as trypsin and amylase inhibitors, phytic acid, and tannins.[12] These compounds are known to interfere with protein, carbohydrates and mineral metabolism. Processing techniques such as fermentation, malting and dehulling techniques have been used to improve nutritional value of ready to eat snacks[12].

Soybean (Glycine max) is a nutritional and economically important crop originated in Asia. Soybean is utilized globally for a healthy diet due to its high contents of iso-flavonoids and folic acid[18]. Dietary Soy products are the subject of increasing scientific interest due to their potential beneficial impact on human health[3]. The important soy components that exhibit biological activity are proteins or peptides, saponins, isoflavones, and protease inhibitors. Soybean and its components possess anti-oxidant, anti-diabetic, antiproliferative, anti-obesity and anti-inflammatory properties[11]. Their consumption has been correlated to various potential health benefits and in the reduction of numerous chronic illnesses like cardiovascular disease, diabetes, immune disorders, certain types of cancer, and obesity[11].

Sweet potato (Ipomoea batata), is an extremely versatile and nutritious crop that serves as a very good vehicle for addressing some health-related problems[15]. It is a source of macro and micronutrients such as carbohydrates, carotenes, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, and vitamin C[14]. Sweet potato can be consumed in different forms such as boiled, fried, or cooked with other staple foods like beans. Despite the potential of sweet potatoes, it is highly underutilized.[17]

A blend of these cheap and culturally acceptable food crops may produce acceptable nutrient dense shelf-stable snacks, which could help in alleviating problems of protein-energy malnutrition and micronutrient deficiency that is prevalent in the developing countries. However, to get maximum nutrient benefit from these crops such as maize, sorghum, sweet potatoes, and brisket bone, they need to be processed to reduce or eliminate inherent anti-nutrients that may interfere with the biological availability of the nutrients. Among the methods used in removing inherent anti-nutrients include roasting, germination, cooking and recently extrusion cooking[16].

1.2 Statement of the Problem

The diets of people in many developing countries comprise mainly starchy foods, cereals, and few legumes; and due to prevailing unfavorable economic conditions in most developing countries, an estimated 400 million are reported to be protein-energy malnourished worldwide. Because fortified snack foods are expensive, many Nigerians rely on poorly processed traditional meals, primarily enriched cereals[5]. Rather than being the result of a vitamin shortage, nutritional rickets is nevertheless common in several tropical nations[22].

1.3 Justification

The development and acceptability of commonly consumed instant extruded snack from blends of maize, sorghum, soybeans, sweet potato and brisket bone can be a vehicle to combat malnutrition and some notable nutritionally non-communicable diseases. According to estimates from the World Health Organization, between 250,000 and 500,000 children worldwide suffer from malnutrition and vitamin A deficiency each year, and half of them die within a year of becoming blind [20,10].

The Project target development of Snacks that is rich in Beta carotene, Protein, Calcium, Fibre, and low in sugar. The development of nutritionally sound snacks could help lower the incidence of diet-related non-communicable diseases such overweight, obesity, diabetes, and cardiovascular disorders as well as prevent the prevalence of malnutrition. This nutritionally dense healthy snacks can also be used as part of the school feeding program, to contribute to the dietary intake of school aged Children.

1.4 Objectives of the study

1.4.1 General Objectives

The Study aimed at evaluating the nutritional and sensory properties of instant extruded snacks made from a combination of malted (yellow maize and white sorghum), soybeans, sweet potato and brisket bones.

1.4.2 Specific Objectives

The specific objectives were to ;.

- Standardize the composite recipe in various proportions.
- Formulate composite flour blends in various proportion.
- Produce the instant extruded snacks from composite flour blends.
- Evaluate the proximate, nutritional and pasting characteristics of the developed Snacks.
- Evaluate the sensory characteristics and the acceptability profiles of the developed product.

1.5 Significance of the Study

This study will contribute valuable insights into the development of extruded snacks with a focus on nutritional content, micronutrient composition, and sensory attributes. The findings have practical implications for both the food industry and consumers interested in diverse and nutritionally rich snack choices. The project contributes to policy formulation and increase literature base on Instant Extruded Snacks.

Endnotes

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Chapter Two

Literature Review

2.1 Snacks

Snacks are small meals that are often made from one or more staple foods and consumed in between meals.[1] Snack foods have a big impact on general nutrition and have become a staple in the diets of many people, especially kids. Because of their convenience, accessibility, attractiveness, flavor, and texture, ready-to-eat snack foods are becoming more and more popular with consumers.[1] They are convenient items commonly high in oil and flavored with salt or salty flavourings. Snacks can be manufactured by a wide array of processes. The simpler snacks are those produced from popcorn, dehydrated fruits, peanuts, and nuts and the most complex are those obtained by thermoplastic extrusion.[2]

Snacks have always been an important part of life, and these products represent an important segment of the food industry worldwide, especially in developed countries. Snacking is increasing due to factors such as increases in one-person households, higher proportion of working mothers, and more school-age children.[2]

A snack is typically a small meal consumed in between meals. A snack typically has 200 calories or less, though this can change. Snacks can be found in many different forms, such as commercial snack foods, processed meals, and homemade snacks created with fresh ingredients. Traditionally, snacks are made with a variety of readily available foods from home with little to no preparation. Snacks frequently include sandwiches, cold meats, fruits, nuts, leftovers, and sweets. [2]

Snacks are typically designed to be portable, quick, and satisfying. Processed snack foods, as one form of convenience food, are designed to be less perishable, more durable, and more portable than prepared foods.[3] They often contain substantial amounts of sweeteners, preservatives, and appealing ingredients such as chocolate, peanuts, and specially designed flavors (such as flavored potato chips).[3] Aside from the use of additives, the viability of packaging so that food quality can be preserved without degradation is also important for commercialization.[3]

The consumption of snack products has increased recently; new trends show that instead of just eating the three main meals each day (breakfast, lunch, and dinner), it appears that people prefer to eat smaller amounts of food more frequently.[4,5] Snacking behavior in adults around the world seem to follow a similar pattern. In Northern Ireland, the most common snacks consumed were savory snacks such as potato chips, or breadsticks, bakery products, sweets, and chocolate. In Finland, the main consumed snacks were classified as sweet bakery, sweets, chocolate, bread, milk and milk products, coffee or tea, water, and interestingly alcoholic beverages.[6] A study conducted in Norway showed that the top five energy-contributing food groups from snacks were cakes, fruits, sugar/sweets, bread, and also alcoholic beverages.[7] In the United States, studies have found that fruit, cookies, ice cream, popcorn, soft drinks, crackers, milk, tea, yogurt, candies, nuts/seeds, desserts, and salty snacks were the preferred types of snacks.[8,9] In China, fruits, grains, and beverages were the most popular snacks and higher contributors to snacking energy, according to a study conducted in this Asian country .[10] As noted from these studies, even if adults lived in different parts of the world, their snacking choices were similar.

2.1.1 Classification of Snacks

Snack foods have been classified in various ways over time and although there is no formal classification, the most accurate ways to classify snacks are based on the manufacturing processes used, the raw materials used, their taste, and their nutritional quality.[11]

Most snacks are produced primarily from maize and wheat and these create products with little or no nutritional properties, thus affecting health due to the added sugar, fat, salt, and dressings. Some of the requirements of healthy snacks are that they possess a balanced nutritional profile of calories, fats, carbohydrates, proteins, vitamins, minerals, and fiber.[12]

The current trend in the food industry is the production of snacks with better nutritional qualities as snack consumption has drastically increased despite the fact that snacks do not represent a nutritious option.[13] This consumption habit can be exploited to turn snacks into a vehicle to provide nutritional good quality supplies to consumers. For example, one current trend is to produce snacks that are rich in protein as these can provide 10%–12% of total energy from protein.[13] There are several processes for the preparation of snacks, but one of the most versatile is extrusion.[13]

Table 2.1.1 Categories of Snacks Food[14]

Category	Products
Hot snacks	
	Minipizzas, pizza baguettes, etc., toasts au gratin, cup noodles, spring rolls, filled croissants
Cold snacks	
Milk and dairy products	Yogurt, plain or with fruit, mini cheese cubes
Bakery products	Cake bars, minitarts, biscuits
Bars	Granola or muesli bars, chocolate bars, minibreak bars, energy bars
Savory products	Chips (crisps), sticks, crackers, pretzels, salt sticks
Other products	Popcorn, puffed cereals, rice snacks, fruit sticks, dip sticks, tortilla chips, fruit snack

	bar
Confectionery	Plain cookies, deposit cookies, macaroons, wire-cut cookies
Extruded snacks	Potato sticks, cereal-based tubes with cheese filling, corn pellets and chips
Low-pressure extruded fried snacks	Sev, omumbadi, murukku
Nut-based snacks	Roasted peanuts, fried peanuts, coated and fried peanuts, toasted and salted pecans, roasted and salted almonds, sugared and spiced nuts, flavored nuts and nut mixtures
Legume-based snacks	Fried green peas, chick peas, lentils, dhals, fried products from bengalgram meal
Meat-based snacks	Expanded pork rinds or skeen, jerky, chimni

2.1.2 Snacking and Health Outcome

2.1.2.1 Snacking effects on Oral Health

Oral hygiene is one of the most important components of dental health. In a stable mouth state, meals, chemicals, and temperature are among the environmental elements that bacteria are exposed to while living in the oral cavity.[15] However, a variety of oral disorders, including periodontal and dental caries, are caused by dysregulations in defense mechanisms.[15] Hygiene measures such as tooth brushing, rinsing, and developing healthy eating habits early in childhood are also critical for maintaining good long-term dental health.[15] Although sugary snacks may be favored due to their flavor, they are not the best for teeth. In this instance, snack frequency matters far more than food consumption quantity.[15]

2.1.2.2 Snacking Effects on Metabolism

The pace of feeding over the day contributes to significant variations in the metabolism of an equal 24-hour energy intake.[16] The daily timing of the supply of nutrients combined with the daily/circadian metabolism regulation causes a switch in the substrate of choice, such that late-night snack sessions result in significantly reduced lipid oxidation compared to breakfast sessions.[16] Once the subjects began sleeping after eating a late-night snack meal (the snack session), they catabolized fewer lipids throughout their sleep period than they did when they fasted from dinner to breakfast (the breakfast session). Older adults at risk for metabolic diseases may maintain lipid oxidation and improve metabolic outcomes by avoiding snacking during the evening.[16] High arterial blood pressure in children and adolescents leads to adult hypertension and has been correlated with an elevated risk of early cardiovascular disorders, such as left ventricular hypertrophy and initial atherosclerotic lesions, as well as premature death.[17.18.19] Being overweight/obese with elevated sodium intake is a significant risk factor for hypertension.[20,21] A causal link between salt consumption and blood pressure has been revealed in adults.[22,23]

2.1.2.3 Snacking Effects on Diabetes

The frequency and size of meals, with significant effects on human well-being, are essential aspects of nutrition.[24] A hypocaloric diet is a central component of type 2 diabetes prevention and recovery and is typically split into three main meals with two to three snacks in between.[24] Consuming snacks is frequently recommended as a way of regulating body weight and glycemic control; however, studies supporting this practice are missing. Snacking leads to weight gain and increased risk of type 2 diabetes.[25,26,27] Snacking facilitates higher energy consumption by increasing food triggers,[28] the desire to eat, and feelings of hunger,[29] which is entirely counter-productive to the treatment of type 2 diabetes.[24] Therefore, it may be more useful (for glycaemic control) to eat larger food portions, rich in fibre than to break food intake into smaller portions.[30] On the other hand, snack consumption could increase towards the night-time period when insulin sensitivity decreases due to natural circadian rhythms and this may lead to hyperglycaemia.[31]

2.1.2.4 Snacking effects on Obesity

Eating unhealthy snacks contributes to the generation of positive energy, in which the energy produced is greater than the energy used, resulting in obesity.[32] Consumption of calorie-dense foods as snacks contributes to higher weight status.[33] Snacking behavior has been used to analyses dietary trends, especially in the study of the prevalence of overweight and obesity.[34] Patterns of snacking can contribute to excessive energy consumption and can therefore affect weight status.[35] Snacks can lead to a rise in calorie intake every day.[36] Previous studies have shown that snacks are mostly highly processed foods that are higher in fat, sugar, and salt.[36] Until now, observational and interventional studies have not sufficiently shown a causal relation between snack food and obesity, which may differ according to the different types of snacks and the measures used to detect obesity.[37] Studies indicated that chronic diseases, including obesity, are linked to snacking,[35,38] whereas other studies confirm that snacking is good for health and has no effect on body weight when healthy snacks such as fruits and vegetables are consumed and snacks high in sugar and saturated fats are avoided.[35,39]

2.1.3 Generations of Snacks

First-generation snack foods: In this category, all the natural products used for snacking, nuts, potato chips, and popped popcorn, are included.[40]

Plate 2a: First-generation snack foods[114].

Plate 2b: Multi-grain chips[114].

Second-generation snack foods: The majority of the snacks such as all the single-ingredient snacks, simple-shaped products like corn/tortilla chips and puffed corn curls, and directly expanded snacks are included in this category.[40]

Plate 3: Second-generation snack foods[114].

Third-generation snack foods (also called half-products or pellets): In this category, snacks and pellets formed using multi-ingredients, made by extrusion cooking, are included.[40]

Plate 4 (a–d) Third-generation snack foods. (e) Example of coextruded snacks[114].

2.2 Ready to Eat Snacks

Ready-to-eat (RTE) snacks are a group of food products that are pre-cleaned, precooked, mostly packaged and ready for consumption without prior preparation or cooking.[41] According to the 2009 US Food code (FDA, 2009), RTE foods should be in an edible form without an additional preparation step to achieve food safety. Foods in this category usually contain raw materials of animal origin, such as eggs, fish, meat, poultry and ratites, and must be cooked to allow the lowest internal temperature to reach a minimum temperature, for a minimum holding time, during manufacturing to destroy microorganisms of public health concern.[41] In an industrial setting, the cooking step is achieved by thermal processing using steam, hot water, microwave, or infrared. The thermal process should be designed by a thermal process authority and should ensure a minimum lethality (F_0) for the target microorganism (usually a foodborne pathogen).[40] A properly processed and packaged ready to eat food should be free of the target foodborne pathogen and ready for consumption.[41]

The majority of these deaths as well as cases of listeriosis occur following consumption of ready-to eat snacks. A significant property of ready to eat foods is their ability to support or inhibit growth of such pathogens and as such they are divided into two categories: high- and low-risk RTE foods.[42]

2.2.1 High-Risk foods

High-risk foods are ready-to-eat foods that can support growth of pathogenic microorganisms which are also more likely to be implicated in food poisoning cases. They are usually high in protein content, require strict temperature control and protection from contamination and include:[42]

Cooked meat and poultry such as beef, pork, ham, lamb, chicken, turkey, duck.

Cooked meat products such as meat pies and pasties, paté, meat stock and gravy, cook-chill meals.

Dairy products such as milk, cream, artificial cream, custards, products containing unpasteurized milk, ripened soft and molded cheeses.

Egg products such as cooked eggs, quiche and products containing uncooked or lightly cooked eggs, mayonnaise, mousse, homemade ice cream.

Shellfish and other seafoods such as mussels, cockles, cooked prawns, raw oysters.

Farinaceous dishes including cooked rice, pasta, couscous.

2.2.2 Low-Risk Foods

Low-risk foods are ambient-stable, such as bread, biscuits, cereals, crisps, and cakes (not cream cakes). Such foods are unlikely to be implicated in food poisoning and include:[42]

- Foods that have been preserved, for example, smoked or salted fish.
- Dry foods, those that contain minimal amounts of moisture, such as bread, flour, biscuits.
- Acidic foods, for example, pickled foods, vinegar, and fruit.
- Fermented products such as salami, pepperoni.
- Foods with high sugar/fat content, for example, jam or chocolate.
- Canned food, whilst unopened.[42]

2.2.3 Acidic Foods

Acidic foods are those that have a pH of 4.6 or below. "Low-acid foods" are foods, other than alcoholic beverages, with a final equilibrium pH greater than 4.6 and a water activity (aw) greater than 0.85.[42] "Acidified foods" are low-acid foods to which acid(s) or acid food(s) are added. These products might be called "pickles" or "pickled" and include beans, cucumbers, cabbage, artichokes, cauliflower, puddings, peppers, tropical fruits, fish, vinegar, fruits, cheeses, and other fermented products such as tempeh, miso, sauerkraut, kefir, kombucha, and kimchi. Although most bacteria are unable to survive in acid-containing foods, bacteria like Salmonella, E. coli, Clostridium botulinum, Clostridium perfringens, and Listeria monocytogenes can survive in some of them.[42]

2.3 Classification of Food Plants for Snacks

2.3.1 Cereals as Snacks

Cereals are the fruits of cultivated grasses, members of the monocotyledonous family Gramineae.[43] Grasses are, in human terms, perhaps the most economically important plant family. Its' economic importance stems from several areas, including food production, industry and lawns. Agricultural grasses grown for their edible seeds are called cereals.[43] Three cereals- rice, wheat and maize (corn) provide more than half of all calories eaten by humans. Of all crops 70% are grasses. Cereals constitute the major source of carbohydrates and perhaps major source of protein.[43] Today, cereals and cereal-based products are an important part of the diet in most countries, and each year new products based on cereals are developed and marketed to increasingly sophisticated consumers. The cereal products include rice, wheat, flour, bread, pasta, snack foods and various bakery product.[43]

2.3.1.1 Rice

Rice is the seed of the monocot plant of the genus Oryza and of the grass family Poaceae (formally Graminae) which includes twenty wild species and two cultivated ones, Oryza sativa (Asian rice) and Oryza glaberrima (African rice).[44] Many products made with flour, such snacks, are made using wheat flour. However, rice flour can be used in place of wheat flour because it doesn't contain gluten, has a low salt content, and a lot of quickly digested carbs, which makes it a good option for celiac diets. Therefore, using rice to make snacks is a viable option.[45]

2.3.1.2 Wheat

Wheat is the most important stable food crop for more than one third of the world population and contributes more calories and proteins to the world diet than any other cereal crops.[46,47,48] It is nutritious, easy to store and transport and can be processed into various types of food. Wheat is considered a good source of protein, minerals, B-group vitamins and dietary fiber.[49,50] although the environmental conditions can affect nutritional composition of wheat grains with its essential coating of bran, vitamins and minerals; it is an excellent health-building food. Wheat flour is used to prepare bread, produce biscuits, confectionary products, noodles and vital wheat gluten or seitan.[50]

2.3.1.3 Sorghum

Sorghum (Sorghum bicolor (L.) Moench), a tropical plant belonging to the family of Poaceae, is one of the most important crops in Africa, Asia and Latin America. More than 35% of sorghum is grown directly for human consumption. The rest is used primarily for animal feed, alcohol production and industrial products .[51] Sorghum grains like all cereals grains are comprised primarily of starch. It is estimated that more than 300 million people from developing countries essentially rely on sorghum as source of energy.[52] The main foods prepared with sorghum are: tortillas (Latino America), thin porridge, e.g. "bouillie" (Africa and Asia), stiff porridge, e.g. tô (West Africa), couscous (Africa), injera (Ethiopia), nasha and kisra (Sudan), traditional beers, e.g. dolo, tchapallo, pito, burukutu, etc. (Africa), ogi (Nigeria), baked products (USA, Japan, Africa), etc. Tortillas are a kind of chips prepared from sorghum alone or by mixing sorghum with maize and cassava.[53] Nasha is a traditional weaning food (infant porridge) prepared by fermentation of sorghum flour. Ogi is an example of traditional fermented sorghum food used as weaning food, which has been upgraded to a semi-industrial scale.[54] Injera is a local fermented pancake-like bread prepared in Ethiopia from sorghum. Kisra is traditional bread prepared from fermented dough of sorghum. Tô is prepared by cooking slurry of sorghum flour. Thin porridges (usually used as weaning food) are also prepared in the same manner with less amount of flour to obtain a fluid end-product. Often sorghum porridges are characterized by thick pastes that may form rather stiff gels depending on variety used. Porridges prepared with malted sorghums have several order of magnitudes lower viscosities than those of non-malted sorghums.[57] These porridges are particularly useful for the formulation of weaning foods for infants because of their high energy density.[58] Sorghum alone is not considered as a bread making cereal because of the lack of gluten, but addition of 20-50% sorghum flour to wheat flour produces excellent bread.[59,60] Among interesting features of sorghum utilization is biscuits and other cooked products.[61]

Sorghum is locally used in wide range of food preparations (thick and thin porridges, steam-cooked and boiled rice-like products, fermented and unfermented breads and snack foods. But Sorghum is found to contain many antinutritional factors such as, tannins, phytic acid, proteinase inhibitors and cyanogenic glycosides. Tannins are reported to interact with proteins (both enzymes and non-enzyme proteins) to form tannin-protein complexes resulting in inhibition of digestive enzymes. Phytic acid is found to form complex with minerals, leading to lower mineral bioavailability.[62] Malting, which involves soaking, germination and drying, aims to change grains into malt with high enzymes and vitamins content. Malting induces important beneficial biochemical changes in sorghum grains. Indeed, soaking generates grain softening and increase water availability. The enzymes will be produced during germination lead to the hydrolysis of starch and proteins with release of sugar and amino acids directly available. Proteolytic enzymes improve amino acid availability, particularly lysine, methionine and tryptophan that are lacking in cereals and contribute to the reduction of phytate level of grain and improve iron and zinc availability.[63]

2.3.1.4 Corn

Maize (zea mays), is among the most important and most widely grown cereal grain in the world. Maize is a grain of importance as typified in its global high rate of production.

In 2007, the global maize grain production stood at 766 million tonnes with United State of America being the largest producer with 40% of the total global production.[64] Almost half of the world production of maize is produced from the developing countries including Nigeria.[65] Its applications include but not limited to human consumption, feeds for livestock, bio-fuel production and as raw material for many industrial applications.[66]

Maize is a staple in some baked goods such as corn muffins, corn bread and breads. Made from maize, corn starch and corn flour are found in many cookies.[67] Corn oil and popcorn are also maize products. Indian maize pancakes, maize bake and enchiladas are also maize products. Corn chips, polenta and nacho chips are also made from maize. Other food products made with corn include potato chips, peanut butter and margarine. Some cheese spreads and chewing gum also feature maize.[67]

2.3.2 Legumes as Snacks

Legumes belong to the family of Fabaceae or Leguminosae and consist of three subfamilies namely Faboideae, Mimosoideae and Caesalphinioidae. It is a dehiscent plant that is ranked as the third largest family of angiosperms composed of more than 20000 species and 750 genera.[68] It is rich in in protein with essential complex carbohydrates, amino acids, unsaturated fats, dietary fibre, vitamins and essential minerals, but the consumption of legumes worldwide is still considerably low which is below 3.5 kg per capita per year.[69] Legume seeds (pulses or grain legumes) are the major source of human food second only to cereal (Poaceae). Nutritionally these are rich in protein content than cereal grains. When legumes and cereals are eaten together, they provide complete protein requirement.[70] Well-known legumes include beans, chickpeas, peanuts, lentils, lupins, mesquite, carob, tamarind, alfalfa, and clover. Legumes produce a botanically unique type of fruit – a simple dry fruit that develops from a simple carpel and usually dehisces (opens along a seam) on two sides.[71]

2.3.2.1 Soybean

Soybean is a species of legume native to East Asia, widely grown for its edible bean, which has numerous uses.[72] Soybeans contain significant amounts of phytic acid, dietary minerals and B vitamins. Soy vegetable oil, used in food and industrial applications, is another product of processing the soybean crop. Soybean is the most important protein source for feed farm animals (that in turn yields animal protein for human consumption).[73]

Traditional unfermented food uses of soybeans include soy milk, from which tofu and tofu skin are made. Fermented soy foods include soy sauce, fermented bean paste, nattō, and tempeh. Fat-free (defatted) soybean meal is a significant and cheap source of protein for animal feeds and many packaged meals. For example, soybean products, such as textured vegetable protein (TVP), are ingredients in many meat and dairy substitutes.[74]

2.3.3 Tubers as Snacks

After cereals, root and tuber crops are the most important food crops.[75] They produce the most dry matter per day and contribute a significant amount of calories. Tuber crops play an essential role in the diets of small and marginal farmers, as well as tribal populations' food security.[75] Tuber crops not only add variety to people's diets, but they also have medicinal characteristics that can help to heal or prevent a variety of maladies. Stimulants, tonics, carminatives, and expectorants are made from a variety of tropical tuber crops.[75] Dietary fiber and carotenoids, such as carotene and 124 Pandemics and Innovative Food Systems anthocyanin, are abundant in tuber crops. Cassava, sweet potato, aroids, yams, and other minor tuber crops are among the genetically diverse tropical root and tuber crops found in India. Roots and tubers are essential components of human nutrition.[75] These crops give a variety of nutritional and physiological benefits, including antioxidative, hypoglycemic, hypocholesterolemic, antibacterial, and immunomodulatory properties, in addition to tubers. Tubers can be used to make a range of dishes, and the type and use of tubers vary by country and region.[75] Tubers may be used as nutritional foods and nutraceutical additives to prevent non-communicable chronic diseases and maintain health. Many nutritional diseases are connected to Vitamin A, Vitamin C and Calcium insufficiency can be easily mitigated by eating root and tuber crops such cassava, sweet potato, yam, and aroids. Minerals and vitamins abound in root and tuber crops. Sweet potatoes, yam, and cassava that have yellow-coloured flesh contain-carotene. Vitamin A is abundant in sweet potato roots and green tips of orange and yellow flesh, which can help avoid night blindness and malnutrition. Sweet potatoes are also abundant in antioxidants like B-carotene, ascorbic acid (vitamin C), and tocopherol (vitamin E), which can help prevent heart disease and cancer. Rice is lacking in lysine, whereas sweet potato contains crucial amino acids. Root and tuber crops, at 500 grams per head per day, are the RDA's recommended dietary allowance. Because these crops are affordable to the poor, they can readily achieve nutritional balance.[76]

2.3.3.1 Sweet Potato

Sweet potatoes are an old crop that originated in South America's northwestern region. The cultivated sweet potato (Ipomoea batatas L.) and closely related wild species are members of the Convolvulaceae family, with the genus Ipomoea, subgenus Eriospermum, section Eriospermum (previously Batatas), and series Batatas.[77] The white/pale-yellow flesh of sweet potatoes is less sweet and moister than the red, pink, or orange flesh. Due to their high carotene content, orange-fleshed sweet potato roots are more nutritious than white/cream-fleshed sweet potato roots. It has high concentrations of vitamins B, C, E, and K, all of which aid in bodily preservation and recovery from sickness. Additionally, sweet potatoes are rich in dietary fiber, minerals, vitamins, and bioactive compounds, such as phenolic acids and anthocyanins, which contribute to the pigmentation of the flesh. High in carotenoids, 125 grams of orange-skinned sweet potatoes increase vitamin

A status in children. This is particularly true for poorer countries. Utilizing orange-fleshed sweet potato genotypes with better yields might enhance the socioeconomic and nutritional status of farmers.[78] Sweet potato, a popular winter root vegetable, is prized for its great nutritional value, flavour, and digestibility. Sweet potatoes are extensively consumed in India after being boiled, baked, or fried. Sweet potato flour, on the other hand, is commonly used in biscuits, cakes, and pudding in other nations. Sweet potatoes have an advantage over other vegetables in that they have a shorter growth period, and inclement weather rarely results in complete crop loss. Sweet potatoes, also known as "poor people's food" or "poor men's produce," have marketing and processing challenges. Sweet potato tuber processing boosts availability and lowers post-harvest waste.[79]

The processed products of sweet potato include:

- Sweet potato flour
- Sweet potato granules
- Canned sweet potatoes

Sweet potato flour can be used to make bread and biscuits, as well as hotcakes, gruel, noodles, candies, puddings, and other dishes. It can be used to make chapatti and bread when combined with wheat flour. In ice creams, this flour acts as a stabilizing agent. Sweet potatoes are a good source of dietary protein, vitamins (Beta carotene, B complex, and vitamin C), minerals, and trace elements, as well as having a high-calorie value.[79]

2.3.4 Brisket Bone

Brisket is a cut of meat from the breast or lower chest of beef or veal. The beef brisket is one of the nine beef primal cuts, though the definition of the cut differs internationally. The brisket muscles include the superficial and deep pectorals. As cattle do not have collar bones, these muscles support about 60% of the body weight of standing or moving cattle. This requires a significant amount of connective tissue, so the resulting meat must be cooked correctly to tenderise it.[80] Beef brisket, whole, lean has a Nutritive Score of 287, making it a medium nutrient-dense food! Plus, it is a low-carb food; beef brisket, whole, lean has 0.6 grams of net carbs per 3.5-ounce serving. Per serving, beef brisket, whole, lean is a best source (>50% daily value) of coQ10 and vitamin B12 (cobalamin); an excellent source (20-50% daily value) of protein, selenium, taurine, vitamin B3 (niacin), vitamin B6 (pyridoxine), and zinc; and a good source (10-20% daily value) of choline, iron, monounsaturated fatty acids (MUFA), phosphorus, and vitamin B2 (riboflavin).[81]

2.4 Food Extrusion

Food extrusion is a complex and complicated technological process, but very flexible and provides the possibility for processing a range of different raw materials.[82] It involves the application of high heat, high pressure, and shear forces to an uncooked food mass in an extruder to obtain a wide range of products including snacks, ready-to-eat (RTE) cereals, confectioneries, and crisp bread.[83] It may also be described as a process by which a set of mixed ingredients are forced through an opening in a perforated die with a design specific to the food and is then cut to a specified size by blades.[84] Extruded foods are composed mainly of cereals and other starch food sources. The major roles of these ingredients are structure, texture, mouth feel, bulk, and many other characteristics desired for specific finished products.[83] The two factors that most influence the nature of the extruded product are the physicochemical properties of the food and the operating conditions of the extruder. The physicochemical properties considered are; the type of feed materials, their moisture content, the physical state of the materials, their chemical composition (amounts and types of starches, proteins, fats, and sugars), and the pH of the moistened material. On the other hand, some of the most important operating parameters in an extruder are temperature, pressure, the diameter of the die apertures, and shear rate.[85] Extrusion technology has been applied in the production of confectionery products, snack foods, breakfast cereals, dairy products, infant foods, meat analogs, and extenders as well as in oil expelling and recycling food waste.

2.4.1 Classification of Food Extrusion based on their Mode of Operation

2.4.1.1 Cold Extruders

In cold extrusion, food materials are heated below 100 o C, maintaining the temperature for shaping and mixing various foods, like batter, meat, and pasta. The low temperature and consequent low-pressure extrusion reduce issues associated with high cooking temperatures.[86] Preservation of cold extruded products involves chilling, baking, or drying. Packaging is crucial to prevent oxidation and moisture absorption. Cold extruders suit small-scale and household use, while costly extruder cookers are for large-scale industries.[87]

2.4.1.2 Hot Extruders

Hot extrusion involves heating food above 100 o C, using frictional heating to rapidly increase temperature. The heated food passes through barrel sections with small flights to enhance shear and pressure.[88] After shaping, rapid cooling removes moisture in the form of steam. Various shapes like shells, rods, doughnuts, and spheres are formed. Extrusion cooking creates new products such as puffed cereals and expanded snack foods.

The choice between cold extrusion and hot extrusion in food processing depends on the desired product characteristics, processing requirements, energy considerations, and equipment capabilities. Both techniques offer unique advantages and are utilized in creating a wide range of food products with diverse textures, shapes, and functionalities.

2.4.2 Materials Used in Extrusion Processing

Extrusion cooking utilizes diverse raw material combinations, including cereals, grains, starches, tubers, oilseeds, legumes, and meat and proteins.[89] Key characteristics defining these materials include type, physical state, moisture content, pH, and chemical composition (starch, proteins, fats, and sugars). They are categorized by functional roles, such as structure-forming materials, dispersed phase fillers, plasticizers, lubricants, nucleating agents, coloring materials, flavoring substances, and preservatives.[90] Structure-forming materials, like maize starch and flour, form the primary ingredient group. Cereals, pseudocereals, and tubers are used for extruded food. Rich in starches, these ingredients vary in amylose and amylopectin proportions, influencing texture. Dispersed phase fillers, the second-largest group, include plant and animal proteins, legume and pulse proteins, meat, marine proteins, and plant fibre. Proteins generally act as fillers, contributing to structure formation, as in textured vegetable protein.[88] Plasticizers and lubricants (water, oils, emulsifiers) reduce mechanical energy by altering properties like melting points, viscosity, hardness, and shear. Water acts as a plasticizer, reducing interactions exponentially. Oils and fats lubricate the compressed polymer mix and affect eating qualities. Emulsifiers, with higher melting points than triglycerides, behave as oils, providing lubrication. Nucleating agents enhance bubbles in extrudates, refining textures. Ideal nucleates, like baking powder or chalk talc, improve cell number and texture. Color comes from natural materials or post-reaction colors like the Maillard reaction. Flavoring substances (salt, sugars, spices, animal digest, natural, artificial flavors) are added during extrusion or post-treatment. Post-extrusion flavoring has drawbacks like uneven application, contamination risk, stickiness, and additional cost. Other additives include preservatives, antioxidants, vitamins, and minerals, with compounds serving specific purposes.[90]

2.4.3 Quality changes in Foods during Food Extrusion

Extrusion, known for its efficiency and high-volume production of textured foods, also introduces significant quality changes. These changes, affecting structural, textural, and nutritional aspects, can be both positive and negative. The process may enhance nutrient bioavailability but poses a risk of degradation, especially for heat sensitive vitamins and proteins. Managing these changes is vital for ensuring nutritional quality. Additionally, the Maillard reaction during extrusion contributes to flavor, color, and aroma development, enhancing taste and visual appeal.[91]

2.4.4 Effect on Physical and Sensory Characteristics

Extrusion variables such as temperature, moisture, and screw speed have been reported to affect expansion ratio, bulk density, water absorption index, water solubility index, and hardness of extruded foods.[92,93,94,95] The production of characteristic texture is one of the main features of extrusion technology. Fading of color due to product expansion, excessive heat or reactions with proteins, and reducing sugars or metal ions may be a problem in some extruded foods.[96]The process conditions used in extrusion cooking such as high barrel temperatures and low feed moistures favor the Millard reaction and also decrease the nutritional availability of lysine.[97] Increasing protein content at constant feed moisture content causes an increase in brittleness, hardness, and crispness but decreases the color intensity. Flavors are therefore more often applied to the surface of extruded foods in the form of sprayed emulsions or viscous slurries, however, this may cause stickiness in some products and hence require additional drying.

2.4.5 Effect on Micronutrients

Vitamins can be destroyed by the action of temperature or by oxidation. Since extrusion mostly involves thermal treatment at higher temperatures of 100 o C, some loss of vitamins in the processed material is expected, especially of the temperature-sensitive and water-soluble vitamins such as vitamin C.[98] However, because of the HTST-type shock treatment, the extent of losses is lower than with conventional methods such as static long-term cooking. Thiamine being the most sensitive to temperature, is damaged during extrusion depending on the processing conditions, temperature rise, and screw speed. Riboflavin losses are much lower (about 94% retention after extrusion) and decrease with increasing water content in the mixture.[99] Vitamins A and E reveal high stability in extruded products, much higher than in the case of raw materials. According to researchers, it is associated with an increased susceptibility to the extraction of fat soluble vitamins after baro thermal processing.[100] Minerals, characterized as inorganic, heat-stable, solid, crystalline chemical elements, are naturally occurring and cannot be decomposed or synthesized through ordinary chemical reactions. Their heat stability allows for pre-processing fortification without the risk of subsequent damage. Extrusion enhances mineral absorption by mitigating factors that inhibit absorption, including phytates, polyphenols, and other antinutrients. The increased solubility of fibre (which may influence the gastrointestinal tract's mobility and potentially interfere with mineral absorption) as a result of extrusion is also beneficial.[88]

2.4.6 Extrusion of Foods for Human Consumption

Extrusion technology serves as a versatile and pivotal method employed in the production of an extensive array of food products. This includes but is not limited to, the manufacturing of snacks, breakfast cereals, analogues for meat and cheese, supplementary foods, infant foods, and various textured food items, showcasing the adaptability and widespread application of this innovative process.[101]

2.4.6.1 Breakfast and whole Cereal Products

The increasing emphasis on healthy eating and evolving lifestyles has elevated the demand for cereals, especially in the form of extruded foods. Ready-to-eat cereals undergo various cooking and modification processes, such as flaking, toasting, puffing, shredding, or extruding, making them suitable for human consumption with low apparent densities.[102] Additionally, cold extruded products such as pasta make up the diets of many individuals.[103]

Breakfast cereals can be crafted from composite flours containing legumes to compensate for the lack of essential amino acids. Additionally, when made with whole grain flour, BCs become sources of fatty acids and fibres. Grains in BCs provide B-group vitamins, tocopherols, and minerals such as iron, zinc, and copper. Emerging BC products strive for functional appeal, integrating antioxidants (tocopherol, lycopene) and fibres (Beta-glucans, gums, oats, wheat, passion fruit brans) to enhance nutritional benefits.[91, 104]

2.4.6.2 Confectionary and Snack Products

Extrusion cooking, specifically High-Temperature Short-Time (HTST) extrusion, is a versatile method employed in creating a chewy and gelatinized product, such as fruit gums and licorice. The process involves a mixture of sugar, glucose, and starch, where heat plays a crucial role in gelatinizing the starch, dissolving the sugar, and vaporizing excess water, which is then vented from the machine. To enhance the product, colorings, and flavors are introduced to the plasticized material.[88] This technology allows for a high degree of customization. The product's texture, ranging from soft to elastic, can be adjusted by carefully controlling the formulation and processing conditions. Additionally, alterations in shape are achievable by changing the die, providing a dynamic aspect to the production process. A myriad of flavors and colors can be incorporated, offering a broad spectrum of potential products. This includes popular items like crispbread, licorice, boiled sweets, creams, toffee, fudge, and chocolate.[105]Lower pressure/larger die apertures create preforms from pre-gelatinized cereal doughs, expanded into the final product by frying, toasting, or puffing, using residual moisture for rapid expansion. The production of snacks, on the other hand, has progressed swiftly, dividing into three generations. First-generation snacks involve processing whole grains with moisture, cooking, and drying. Second-generation snacks, often marketed as high-fibre, low-calorie, high-protein products, result from extrusion processing of materials like flours, cereals, starches, and proteins. The continuous mass produced is cut, dried, flavored, and stored. Third-generation snacks, termed "half products," exit the extruder in die form and expand through frying or heating later, offering low moisture, high density, and extended shelf life.[106,107] Supercritical fluid injection in twin-screw extrusion cooking unlocks possibilities for innovative processing in cereals, confectioneries, pasta, flavorings, pharmaceuticals, snacks, and beyond.[108]

2.4.6.3 Meat analogues and Extenders

Meat analogues and extenders, also known by various terms such as meat substitute, mock meat, faux meat, or imitation meat, aim to replicate specific aesthetic qualities and chemical characteristics of meat.[88] Their popularity has increased in the past few decades due to the high demand for alternative and cheap sources of protein to cover the nutrition gap. They can be produced using various techniques including extrusion technology and they closely mimic the fibrous structure of meat from animal protein.[109] Meat extenders, produced at low moisture contents (20-35%), and meat analogues, created at high moisture contents (50-70%), have distinct characteristics. Defatted soy flour and soy protein concentrate (SPC) are commonly used for meat extenders, while meat analogues rely on soy protein concentrate (SPC) and soy protein isolate (SPI). Primary vegetable proteins, such as those from soybeans, common beans, peas, and cereals like wheat proteins responsible for gluten network formation, are utilized in the production of meat analogues.[110]

2.4.6.4 Dairy products

Milk protein possesses health benefits and desirable functional properties. When protein is subjected to mechanical shear as in extrusion, considerable changes in the molecular structure of the protein are seen. These changes (texturization) lead to the formation of new protein-based food products. Texturization stretches and shears the protein to form a new fibre bundle-like structure that withstands hydration, cooking, and other procedures.[111] Extrusion technology plays a crucial role in the production of various milk products. It is also employed for stretching and forming operations in cheese making as well as in the production of functional powders with excellent hydration properties.[112]

Plate 5: Second-generation snack foods[113]

Plate 6: Extruded cheese puffs in a white ceramic bowl[113]

Plate 7: Chocolate flavored extruded snack[113]

Plate 8: A tasty selection of yellow snacks[113]

Plate 9: Cheese flavored puffed corn snacks[113]

Plate 10: Cheese flavored puffed corn snacks[113].

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Chapter Three

Materials and Methods

3.1 Material Procurement

Raw Materials (yellow maize, white sorghum, sweet potato, soybeans, and brisket bone) were purchased from Arena Market in Bolade Oshodi, Lagos State, Nigeria.

3.1.2. Preparation and Processing

The processing of the raw materials into respective flours was carried out in the Food Processing Pavilion of the Federal Institute of Industrial Research, Oshodi (FIIRO), after which they were transported to the Federal University of Agriculture Abeokuta

(FUNAAB), Department of Food Science and Technology, where they were processed through a hot extruder to formulate composite flour and produce instant extruded snacks. The processing techniques of the individual flours are as stated.

3.2. Production of Flours

3.2.1 Production of Sweet Potato Flour

Freshly harvested sweet potatoes were prepared according to a technique.[1] The newly harvested tubers were submerged in water containing 0.1 percent ascorbic acid for approximately 30 minutes after being cleaned with potable water. After that, they were emptied and dried in a Mitchel Cabinet drier set to 60^0C until the moisture level was less than 10%. After that, the material was ground into roughly 250 micron-sized particles using an Apex Hammer mill, allow to cool, and then packaged in a PP/PE laminate pouch until needed.

Freshly harvested sweet potato tubers

↓

Sorting / Washing

↓

Peeling into water containing 0.1% Ascorbic acid

↓

Slicing, into water containing 0.1% ascorbic for about 30mins

↓

Draining

↓

Drying (at 60^{O}C using Mitchell cabinet dryer)

↓

Cooling/milling using a hammer mill with mesh ap 0.027inches)

↓

Cooling and packaging using pp/pe stand-up pouches

↓

Storing in a cool dry place

Figure 3.1: Flow chart showing the Production of sweet potato flour.[1]

3.2.2. Production of Malted Grains (Yellow Maize, Sorghum, Soya Beans) Flours

Malted Grains (Yellow Maize, White Sorghum and Soybeans) flours were obtained.[2]

Viable Grains were sorted, washed, conditioned in water at a temperature of 60^0C for 60mins in order to reduce the microbial action which could be manifesting during malting, then drained and lightly hipped on malting trays, cover with a cloth and kept in a warm dark place for 20 hours (Sorghum) and 30 hours (yellow maize and Soybeans) to allow sprouting to take place After which the sprouts were washed drained and dried using a Cabinet dryer at a temperature of 60^0C till the moisture content of less than 10%

is achieved. They were then allowed to cool, de-rooted and then milled to a particle size of 350 microns, cooled and packed using a PP/PE laminate Pouch until use (Figure 2).

Viable Grains (Maize & Sorghum)

↓

Sorting / Washing

↓

Conditioning in hot water of 600c for 60mins

↓

Draining

↓

Lightly hipped on mesh tray

↓

Sprouting

↓

Washing/Draining

↓

Drying using a cabinet dryer at 60^0c

↓

Milling using a hammer mill with 0.027inches mesh

↓

Cooling and packaging

↓

Storing in a cool dry place

Figure 3.2: Flow Chart for Production of malted flours.[2]

3.2.3. Production of Un-Malted Soya Beans Flour

Soybeans grains were cleaned, sorted, dehulled and aspirated. After which they were washed, soaked in potable water for two hours and then boiled for 30mins to remove the antinutrients in them and then allowed to cool, washed again and dry at $60^0{}_C$ till the moisture content of less than 10% was achieved[2]. The Apex Hammer was used to mill it after letting it cool. Before being stored in PP/PE laminate pouches until needed, a 0.027-inch mesh size was used (Figure 3.3).

Wholesome soybean grains

⇓

Cleaning/Sorting

⇓

Conditioning /De-hulling

⇓

Washing/Soaking to hydrated

⇓

Boiling for 30mins

⇓

Draining/ Cooling/washing

⇓

Drying at 600c, using a cabinet dryer

↓

Cooling

↓

Milling using a hammer mill with 0.027inches mesh

↓

Cooling and packaging

↓

Storing in a cool dry place

Figure 3.3. Flow chart showing the production of Soybeans flours[2].

3.2.4 Production of Brisket Bone powder

A Fresh Brisket bone was obtained , the fleshy part were removed using sharp knife, the bone were washed cut into smaller pieces boiled in water containing 0.5% ascorbic acid which is an antioxidant(for prevention of oxidation during the entire processes) before being used,drained and dried using Cabinet dryer at 60^0C until moisture content of less than 10 % is achieved, It cooled, and milled using Hammer mill with mesh size of 0.027 inches, cool and package using PP/PE Laminate until use (Figure 3.4).

Fresh brisket bones

↓

Removal of the adhered flesh from the bone

↓

Size reduction

↓

Washing/Cleaning

↓

Draining

↓

Drying using a cabinet dryer at 60^0C

↓

Cooling/Milling using a hammer mill (with 0.027inches)

↓

Cooling/Packaging (using pp/pe pouches and store)

Figure 3.4. Flow Chart showing the Production of Brisket Bone Powder[2].

3.3 Extrusion

A total of nine combinations, based on preliminary trial were generated for the independent variables (Maize. Sorghum and Maize/Sorghum with three centre points).

3.3.1. Composite Flours Formulation

The Samples were formulated according to The Dietary Guidelines of Acceptable Macronutrients Distribution Ranges (AMDR) for adults, by United States Department of Agriculture (USDA), as stated below;

- Carbohydrates: 45–65% of daily calories
- Protein: 10–35% of daily calories
- Fat: 20–35% of daily calories

The nine composite flours used in the production of Instant extruded Snacks were formulated in three segment (A,B,C), as indicated in Table 3.1,3.2 and 3.2. below A is Maize based (ASO, BSO, CSO), B is Sorghum based (DSO, ESO, FSO), while C is maize -sorghum based (GSO, HSO, ISO).

3.3.2. Preliminary Trials of Composite Flour Formulations

Preliminary trials and sensory evaluation of nine formulations were carried out in three segments A, B, C. A is Maize based (ASO, BSO, CSO), B is Sorghum based (DSO, ESO, FSO), while C is maize -sorghum based (GSO,HSO,ISO) ,in the ratio showed in the Tables 3.1,3.2 and 3.3 above. The sensory results from the preliminary trials gave snacks that were rated below average in some sensory attributes in term of taste, colour, crispiness, hardness, aroma, which were observed to be a result of high soybeans inclusion, prolong malting hours and some other processing methods and this led to the adopted formulation.

SEGMENT A

Table 3.1 Ingredient proportions (g/100g) in the tested recipes for maize, sweet potatoes, soybeans, and brisket bones

S/N	Samples Codes	Maize flour(mf) (%)	Sweet potato flour(pf) (%)	Soya flour (sbf)(%)	Brisket bone (bf)(%)
1	ASO	70	20	5	5
2	BSO	65	20	10	5
3	CSO	60	20	15	5

Where:

ASO= 30hrs Malted Maize 70%, Sweet Potato Flour 20%, Soyabean 5% and Brisket Bone 5%.

BSO= 30hrs Malted Maize 65% Sweet Potato Flour 20%, Soyabean (10%) and Brisket Bone 5%.

CSO= 30hrs Malted {Maize (60%) Sweet Potato Flour 20%, Soyabean (15%) and Brisket Bone 5%.

SEGMENT B

Table 3.2 Ingredient proportions (g/100g) in the tested recipes for sorghum, sweet potatoes, soybeans, and brisket bones

S/N	Samples Codes	Sorghum flour(sf) (%)	Sweet potato flour(pf) (%)	Soya flour (sbf) (%)	Brisket bone (bf) (%)
4	DSO	70	20	5	5
5	ESO	65	20	10	5
6	FSO	60	20	15	5

Where:

DSO= 20hrs Malted Sorghum (70%), Sweet Potato Flour 20%, Soyabean 5% and Brisket Bone 5%.

ESO= 20hrs Malted Sorghum (65%), Sweet Potato Flour 20%Soyabean (10%) and Brisket Bone 5%.

FSO= 20hrs Malted Sorghum (70%), Sweet Potato Flour 20% Soyabean (15%) and Brisket Bone 5%.

SEGMENT C

Table 3.3 Ingredient proportions (g/100g) in the tested recipes for maize, sorghum, sweet potatoe, soybean, and brisket bone

S/N	Samples Codes	Maize flour(mf) (%)	Sorghum flour(sf) (%)	Sweet potato flour(pf) (%)	Soya flour (sbf)(%)	Brisket bone (bf)(%)
7	GSO	35	35	20	5	5
8	HSO	32.5	32.5	20	10	5
9	ISO	30	30	20	15	5

Where:

GSO= 30hrs Malted Maize 35% +20hrs sorghum (35%), Sweet Potato Flour 20%, Soybeans (5%) and Brisket Bone 5%.

HSO=30hrs Malted Maize 32.5% +20hrs sorghum 32.5%, Sweet Potato Flour 20%, Soybeans 10% and Brisket Bone 5%.

ISO=30hrs Malted Maize 30% +20hrs sorghum 30%, Sweet Potato Flour 20%, Soybeans 15% and Brisket Bone 5%.

3.3.3. Extrusion of Mixed Ingredients

The composite flour blends were extruded using a twin-screw extruder that was commercially available, Qitong Chemical Industry Equipment Co. Ltd., Yantai, China; Model JS 60 D.[3] Samples of composite flour mixes were moistened to a 20 percent moisture level using water. From an initial moisture content of less than 10% prior to extrusion.

The composite flour samples were extruded at the starting, cooking and ejecting (zones A, B, C) temperatures of 60^0c, 120^0c and 140^0c respectively, the feeder speed rate was 10.76 rpm, while the motor speed was 24.76 rpm.[4,5] The Snacks were allowed to cool at room temperature after extrusion, before being packaged in PP/PE laminate and served as snacks or meals, depending on the preferences of each individual. After being ground into granules using an Apex Hammer mill with a mesh size of 0.031 inches, the extruded flour was also presented in this manner. Before the analysis was finished, the extruded flours were stored at room temperature, 25 to 30 degrees Celsius, in PP/PE polyethylene pouches.

3.4. Proximate Composition Determination

The Association of Official Analytical Chemists (AOAC),2023 criteria were followed in determining the extruded product's proximate composition, which included dry matter, crude fibre, ash content, protein, crude fat, and carbs. The findings were displayed as the average of determinations made in triplicate. Using normal protocols, proximate analysis of the Snacks was performed in triplicate.

3.4.1. Moisture Content Determination

The AOAC (2023),described method was used to determine the moisture content. After being cleaned, the crucibles was cooled in a desiccator and dried in an oven at 100 ºC for an hour to achieve a constant weight (w1) (w2). After weighing two grams of the material into the crucible, the dish with the sample was placed in a preheated oven set at 105°C for 2-hours until a consistent weight was achieved (w3).The dish was removed from the oven and placed in a desiccator to cool to a room temperature, the sample with the dish was weighed, recorded and the moisture content was calculated

The percentage of moisture was calculated as indicated below

$$\% \, Moisture = \frac{(w2 - w3)}{(w2 - w1)} \times 100$$

Were

W1= Crucible weight in empty; W2 = dish weight plus sample prior to drying;

W3= dish weight plus sample following drying.

3.4.2. Crude Fiber Determination

The crude fiber was determined using the AOAC (2023) method. Petroleum ether was used to defat 2g of the sample. 1.25% H_2SO4 were mixed with it, and boiled for 30 minutes . The mixture was filtered, residue washed with hot distilled water and later with acetone to remove any remaining alkali. The residue was dried in an oven at 105^0C, cooled, and weighed until a constant weight was archived. And then the dried residue was incinerated at 525^0C to eliminate all the organic matters ,and weighed to determine in organic content. So, the crude fibre was calculated as follow

$$\%crude\ fibre = \frac{W1-W2}{Wo} \times 100$$

Where; W_0 = sample weight; W_1 = the dried sample's weight; W_2 = the sample that was reweighed

3.4.3. Ash Content

The AOAC (2023) technique was utilized to ascertain the content of ash. Weighing (w1) 2 g of the finely powdered noodle sample into a crucible that has been heated and cooled. This sample was burned in a fume cupboard using a Bunsen flame (sw2). The sample was placed in a muffle furnace that has been preheated to 550^0C for 4 hours, or until a white or light grey ash is produced. After cooling in a desiccator, it was weighed (w3). The percentage of ash was calculated as indicated as below:

$$\%\ Ash\ = \frac{Ash\ weight\ (g)}{Sample\ weight\ (g)} \times\ 100 \ldots\ldots Eqn\ 3.5$$

3.4.4. Crude Fat

The AOAC (2023) Soxhlet extraction method was used. A clean round bottom flask of 500ml and a Soxhlet extractor with reflux condenser were fixed. A thimble with a label was used to weigh a sample of 2g, dried to remove to ensure accurate measurement of fat. The sample was treated with HCL to breakdown the food matrix and bound fat. The hydrolysed sample was transferred into Soxhlet extractor and petroleum ether was used as organic solvent The solvent was heated, vapourized, and condensed to drip onto the sample, dissolving the fat. The extraction process was continued for a period 5hours .The solvent was removed from the extracted fat by heating in a water bath. Then the extracted fat was dried in an oven at 105^0C until a constant weight was achieved, weighed the dried fat to determine the total fat content. The total fat content was calculated using the formula

$$\% \, Fat = \frac{weight\ of\ ether\ extract}{weight\ of\ sample} \times 100 \ldots\ldots Eqn\ 3.6$$

3.4.5. Crude Protein

The micro Kjeldahl technique was used to determine the crude protein content in accordance with AOAC (2023). 2g of the food sample was weighed, placed in a digestion flask and concentrated H_2SO_4 was added, K_2SO_4 was added also as a catalyst. The mixture was heated to a temperature of 370°C until the sample was fully digested and the solution became clear. After digestion, the solution was cooled, diluted with distilled water, transferred to distillation apparatus, NaOH was added into the solution to neutralise the acid. Then, ammonia gas was distilled into a receiving flask containing a known volume of boric acid in a reaction to form ammonium borate. The ammonium borate solution was titrated with a standard solution of HCL to determine the amount of ammonia and methyl red as indicator to identify the end point of the titration. The nitrogen content was calculated using the formula below and the amount of protein was determined using conversion factor of 6.25

$$\% \, crudeprotein = 6.25^{*} \times \%N$$

$$\%N = \frac{(Sampletitrationreading - Blanktitrationreading) \times N \times 0.014 \times Dilutionofsample}{weightofsample}$$

where * = Correction factor 55

3.4.6. Carbohydrate Determination

Carbohydrate content of the samples was determined by difference as described by AOAC (2023) using the equation below:

Total Carbohydrate = (100 – (% moisture +% crude protein +% crude fat + % crude fiber + % ash)[1]

3.4.7. Energy Determination

Atwater's conversion factor was used to compute the energy content. As given below

1g of Carbohydrate yield 4kcal of energy, 1g of fat 9kcal of energy,1g of Protein yield 4kcal.

So, energy(kcal)= [(Percentage Carbohydrate x 4) + (Percentage Fat x 9) + (Percentage Protein x 4)] .

3.4.8 Total Dietary Fiber (TDF)

The TDF was determined using the enzymatic-gravimetric method, according to Barry V. McCleary et al. (2012).[6] It was determined that Dietary fiber comes in two varieties.: insoluble and soluble, which are grouped based on their water solubility. Total dietary fiber (TDF) was calculated via enzymatic digestion and is as follows: Dietary fiber that is soluble plus insoluble (IDF) (SDF)

3.5 Micronutrients Analysis

3.5.1 Mineral Analysis

Phosphorus was measured by the molybdate method using hydroquinone as a reducing agent.[6] Using an atomic absorption spectrophotometer, the quantities of each the determined mineral were ascertained following digestion with a solution of nitric acid and perchloric. (Model GE 712354, Thermo Scientific S Series).[6]

Prior to being broken down, 0.50 g of the samples were weighed in a fume hood into a 125 ml Erlenmeyer flask with 4 ml of sulfuric acid concentrate, 25 ml of concentrated HNO_3, and 2 ml of perchloric acid. In a digester (Buchi Digestion unit K-424), the components were mixed together and cooked over low to medium heat on a hot plate under a perchloric acid fume hood. After 30 seconds of intense heating, the mixture was allowed to cool before 50ml of distilled was added. After cooling, Atomic Absorption Spectrophotometer (AAS)was used to measure the concentration of minerals. The AAS was Calibrated with the standard solutions of known mineral concentrations[6].And the mineral content was calculated using the mineral reading and the dilution factor

3.5.2 Vitamin Analysis

β-carotene extraction and analysis: To evaluate the amount of β-carotene, 1g of the sample was extracted by soaking it in 5ml of methanol in dark room at room temperature for two hours. Hexane was used in a separating funnel to separate the β-carotene layer and was added to the volume to make it up to 10 ml, and this layer was then run through sodium sulphonate once more through a funnel to remove any last traces of moisture. The absorbance of the layer was determined at 436 nm using hexane as a blank.[7]

The formula was used to compute the beta carotene.:

High-Performance Liquid Chromatography (HPLC) was used to measure the concentration of minerals. The HPLC was Calibrated with the standard solutions of known vitamin concentrations. And the vitamin content was calculated using the vitamin reading and the dilution factor.

3.6 Pasting Properties

The pasting properties of the samples were determined following the protocol as previously reported.[9] A paste was formed in pre-weighed canister from each sample using sample mass and volume of water calculated using the moisture content of the respective samples. The canister with the formed paste was fixed into the Rapid Visco Analyzer (RVA Model 4500, Perten Instruments, Australia) for analysis.

Each suspension was kept at 50°C for 1 min and then heated to 95°C in 7.5 min with a holding time of 5 min followed by cooling to 50°C in 7.5 min with a 1-min holding time. The pasting parameters - Peak viscosity, Trough viscosity, Breakdown viscosity, Final viscosity and Setback viscosity were read.

3.7 Sensory Properties of Instant Extruded Snacks

Procedure followed the methodology described by Rathod and Annapure with a little modification. Ten Panellists were used to evaluate the cooked instant extruded snacks for appearance, flavour, texture, taste, mouthfeel, and overall acceptability in triplicate. The strength of the sensory descriptors was rated on a nine-point line scale with scores ranging from 1 to 9. (1 = dislike extremely; 9 = like extremely).

3.8 Statistical Analysis

Every analysis was carried out in triplicate. The findings derived from both sensory and physio-chemical studies were presented as mean ± standard deviation. In the statistical analysis, one-way analysis of variance (ANOVA) was employed, and IBM SPSS 21.0 version was used at P≤0.05level of significant

3.9 Ethical Approval

Participant was properly informed about the study and only those who showed interest was recruited for this study. The ethical approval (LCU-REC/23/315) for this study was sought and obtained from the Ethics Committee of Lead City University, Ibadan, Oyo State, Nigeria.

Endnotes

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Chapter Four

4.0 Results and Discussion of Findings

Table 4.1 shows the proximate analysis of the nine Instant Extruded Snacks samples developed from the flour blends.

The proximate composition of the samples ranged from 4.10% to 4.20% for moisture content, 1.71% to 2.00% for ash, 10.29% to 10.58% for fibre, 12.80% to 14.60% for crude protein, 3.10% to 3.15% for fat and 65.08% to 68.32% for carbohydrate, and 350.27kcal to 358.48kcal for Energy

Table 4.1: g/100g Proximate composition of Instant Extruded Snacks Made from Individual Flour Blend

SAMPLE	MOISTURE	ASH	FAT	PROTEIN	FIBRE	CHO	ENERGY
ASO	4.20^a ± 0.02	2.00^b ± 0.13	3.10^b ± 0.03	12.80^c ± 0.04	10.58^a ± 0.03	68.32^a ± 1.32	352.38

BSO	4.10^{c}	1.80^{c}	3.12^{b}	13.72^{b}	10.37^{b}	67.89^{a}	354.52
	± 0.03	± 0.14	± 0.03	± 0.05	± 0.06	± 1.22	
CSO	4.15^{b}	1.71^{c}	3.15^{ab}	14.40^{a}	10.31^{bc}	66.08^{a}	350.27
	± 0.04	± 0.12	± 0.02	± 0.04	± 0.03	± 1.23	
DSO	4.20^{a}	2.00^{a}	3.13^{ab}	12.90^{c}	10.57^{a}	67.90^{a}	351.40
	± 0.04	± 0.18	± 0.03	± 0.05	± 0.05	± 1.12	
ESO	4.15^{b}	2.00^{a}	3.20^{a}	13.64^{b}	10.38^{b}	67.23^{a}	352.28
	± 0.02	± 0.09	± 0.04	± 0.04	± 0.05	± 1.20	
FSO	4.10^{c}	2.00^{a}	3.10^{b}	14.52^{a}	10.29^{c}	67.49^{a}	355.94
	± 0.03	± 0.11	± 0.02	± 0.06	± 0.04	± 1.21	
GSO	4.10^{c}	1.80^{b}	3.00^{c}	12.92^{c}	10.58^{a}	67.30^{a}	351.88
	± 0.01	± 0.19	± 0.02	± 0.02	± 0.04	± 1.23	
HSO	4.15^{b}	1.90^{b}	3.20^{a}	13.81^{b}	10.38^{b}	67.36^{a}	353.48
	± 0.04	± 0.22	± 0.03	± 0.05	± 0.03	± 1.30	
ISO	4.20^{a}	2.00^{c}	3.10^{b}	14.60^{a}	10.29^{c}	65.01^{a}	358.34
	± 0.02	± 0.13	± 0.01	± 0.06	± 0.06	± 1.15	

Table 4.2 Presents the Micronutrients Analysis of the Nine Instant Extruded Snacks Samples Developed from the Flour Blends. (mg/100g)

The micronutrients composition of the samples ranged from 262.20mg/100g to 268.40mg/100g for Calcium, 137.22mg/100g to 164.22mg/100g for Magnesium, 455.23 to 458.35mg /100g for Potassium,120.00 to145.45mg/100g for Sodium, 370.23 to 403.23mg/100g for Potassium,40.20 to 49.65 mg/100g for Iron ,1.11 to 3.23mg/100g for 0.76mg/100g.

Table 4.2: Micronutrients Values of Instant Extruded Snacks Made from Individual Flour Blend

Parameters (mg/100g)	ASO	BSO	CSO	DSO	ESO	FSO	GSO	HSO	ISO
Calcium	262.20^{b} ± 4.13	263.21^{b} ± 4.32	260.23^{b} ± 5.08	267.20^{ab} ± 4.16	268.40^{ab} ± 5.17	270.10^{a} ± 5.08	261.10^{b} ± 4.16	267.42^{ab} ± 4.30	275.10^{a} ± 5.21
Magnesium	160.23^{a} ± 5.20	162.42^{a} ± 5.18	164.22^{a} ± 5.32	140.29 ± 4.98	142.21^{b} ± 5.02	143.21^{b} ± 4.52	137.22^{c} ± 4.78	138.98^{bc} ± 4.36	140.23^{b} ± 5.30
Potassium	456.50^{a} ± 6.07	455.23^{a} ± 5.87	456.10^{a} ± 6.46	456.33^{a} ± 5.74	457.6^{a} ± 5.56	456.82^{a} ± 5.87	457.43^{a} ± 5.75	458.34^{a} ± 5.28	458.35^{a} ± 4.86
Sodium	145.12^{a} ± 4.86	145.23^{a} ± 4.25	145.45^{a} ± 5.70	120.00^{c} ± 4.96	122.12^{c} ± 4.75	123.21^{c} ± 5.06	136.45^{b} ± 4.92	134.56^{b} ± 5.16	133.61^{b} ± 5.28
Phosphorus	370.23^{c} ± 4.85	380.23^{c} ± 5.23	394.23^{b} ± 5.14	398.32^{b} ± 4.95	394.23^{b} ± 5.33	392.42^{b} ± 5.15	403.23^{a} ± 5.24	401.23^{a} ± 5.72	402.23^{a} ± 4.84
Iron	4.40^{c} ± 1.04	4.20^{d} ± 0.94	4.23^{cd} ± 1.10	4.23^{b} ± 1.48	4.52^{a} ± 1.12	4.65^{a} ± 1.50	4.44^{c} ± 1.82	4.45^{c} ± 1.14	4.43^{c} ± 1.61
Zinc	3.23^{a} ± 0.15	3.10^{a} ± 0.12	3.12^{a} ± 0.14	1.20^{c} ± 0.10	1.11^{c} ± 0.13	1.22^{c} ± 0.14	2.30^{b} ± 0.21	2.31^{b} ± 0.18	2.21^{b} ± 0.22
Vitamin A	4.56 ± 0.22	4.45 ± 0.20	4.36 ± 0.18	3.46 ± 0.19	3.43 ± 0.20	3.45 ± 0.24	4.00 ± 0.26	3.99 ± 0.25	3.98 ± 0.29
Vitamin B1	4.34^{a} ± 0.12	4.32^{a} ± 0.16	4.33^{a} ± 0.11	3.76^{b} ± 0.14	3.83^{b} ± 0.15	3.85^{b} ± 0.18	4.12^{a} ± 0.22	4.03^{a} ± 0.24	3.99^{ab} ± 0.21
Vitamin B2	0.76^{a} ± 0.03	0.74^{ab} ± 0.02	0.74^{ab} ± 0.03	0.70^{b} ± 0.02	0.69^{b} ± 0.03	0.69^{b} ± 0.02	0.73^{ab} ± 0.03	0.72^{ab} ± 0.02	0.72^{ab} ± 0.03

Table 4.3: Presents the Pasting Properties of the Nine Composite Flour Blends Used in Developing the Nine Instant Extruded Snacks.

The pasting properties of composition flour blends samples ranged from 539.00 to 808.50RVU for peak viscosity, 413.00 to 616.50RVU for Trough, 45.00 to 373.00RVU for breakdown, 967.50 to 1437.50RVU for final viscosity, 523.50 to 821.00RVU for setback,4.67 to 7.00mins for peak time , 80.35 to 85.63$^{0}{}_{C}$ for pasting temperature.

Table 4.3: Pasting Properties of composite flours blends used in producing the Instant

	Peak Viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temp (^{o}C
ASO	674.50^{de} ± 31.82	616.50^{a} ± 30.41	58.00^{d} ± 1.41	1437.50^{a} ± 67.18	821.00^{a} ± 36.77	7.00^{a} ± 0.00	83.55^{b} ± 0.57
BSO	610.00^{f} ± 1.14	561.00^{b} ± 2.83	49.00^{d} ± 1.41	1254.00^{b} ± 7.07	693.00^{cd} ± 4.24	7.00^{a} ± 0.00	83.98^{b} ± 0.11
CSO	539.00^{g} ± 1.41	494.00^{d} ± 1.41	45.00^{d} ± 0.00	1121.50^{d} ± 0.71	627.50^{e} ± 0.71	7.00^{a} ± 0.00	85.63^{a} ±1.10
DSO	784.50^{a} ± 14.85	417.00^{f} ± 0.00	367.50^{a} ± 14.85	967.50^{f} ± 2.12	550.50^{f} ± 2.12	4.73^{d} ± 0.00	80.63^{cd} ± 0.04
ESO	808.50^{a} ± 7.78	435.50^{f} ± 6.36	373.00^{a} ± 14.14	1036.00^{e} ± 2.83	600.50^{e} ± 3.54	4.73^{d} ± 0.00	80.68^{cd} ± 0.04
FSO	743.50^{b} ± 3.54	413.00^{f} ± 1.41	330.50^{b} ± 2.12	936.50^{f} ± 9.19	523.50^{f} ± 7.78	4.67^{e} ± 0.00	80.35^{d} ± 0.57
GSO	654.00^{e} ± 16.97	522.00^{c} ± 11.31	132.00^{c} ± 5.66	1186.00^{c} ± 38.18	664.00^{d} ± 26.87	5.00^{c} ± 0.00	81.03^{cd} ± 0.60
HSO	696.50^{cd} ± 4.95	561.50^{b} ± 7.78	135.00^{c} ± 2.83	1284.00^{b} ± 9.90	722.50^{bc} ± 2.12	5.03^{bc} ± 0.05	81.88^{c} ± 0.60
ISO	715.00^{bc} ± 9.90	569.50^{b} ± 9.19	145.50^{c} ± 0.70	1309.00^{b} ± 21.21	739.50^{b} ± 12.02	5.07^{b} ± 0.00	81.45^{cd} ± 0.00

Table 4.4 Presents the Sensory Results for Instant Extruded Snacks Developed From Maize Based Extrudate.

The Sensory scores of the samples ranged from 7.40 to 8.00 for colour,7.40to8.20 for shape, 6.40 to 8.80 for taste, 7.20 t0 8.20 for aroma, 7.00 to 7.60 for crispiness, 6.00 t0 8.60 for sweetness, 6.00 to 7.40 for after taste, 6.40 to 8.80 for overall acceptability.

Table 4.4: Sensory Results for Instant Extruded Snacks Developed From Maize Based Extrudate

Sample	Colour	Shape	Taste	Aroma	Crispiness	Sweetness	Aftertaste	Overall Acceptability
ASO	8.00^{b}	8.20^{c}	8.80^{b}	8.20^{b}	7.60^{a}	8.60^{b}	7.40^{a}	8.80^{c}
	± 0.71	± 0.45	± 0.84	± 0.84	± 0.55	± 0.55	± 0.55	± 0.84
BSO	7.40^{a}	7.40^{b}	7.60^{a}	7.20^{b}	7.40^{b}	7.20^{a}	7.00^{a}	7.00^{b}
	± 0.90	± 0.55	± 0.90	± 0.84	± 0.90	± 0.84	± 0.71	± 1.00
CSO	7.40^{a}	7.60^{a}	6.40^{a}	7.60^{a}	7.00^{b}	6.00^{a}	6.00^{b}	6.40^{a}
	± 0.55	± 0.55	± 0.58	± 0.55	± 0.71	± 0.71	± 0.71	± 0.55

Significant differences are seen between means in the same row with different superscripts ($p < 0.05$).

Table 4.5: Presents the Sensory Results for Instant Extruded Snacks Developed From Sorghum Based Extrudate.

The Sensory scores of the samples ranged from 6.00 to 8.20 for colour,6.60 to 7.80 for shape, 6.00 to 7.80 for taste, 5.40 to 6.60 for aroma, 7.00 to 8.60 for crispiness, 5.80 to 7.20 for sweetness, 4.80 to 6.60 for after taste, and 5.20 to 8.00 for overall acceptability.

Table 4.5: Sensory Results for Instant Extruded Snacks Developed From Sorghum Based Extrudate

Sample	Colour	Shape	Taste	Aroma	Crispiness	Sweetness	Aftertaste	Overall Acceptability
DSO	$8.20^{a} \pm 0.85$	$6.60^{a} \pm 0.89$	$7.80^{a} \pm 0.84$	$6.20^{ab} \pm 0.84$	$8.60^{a} \pm 0.55$	$7.20^{a} \pm 0.84$	$6.60^{a} \pm 0.55$	$8.00^{a} \pm 0.71$
ESO	$6.00^{b} \pm 0.71$	$7.80^{a} \pm 0.84$	$7.20^{a} \pm 1.10$	$6.60^{a} \pm 0.55$	$7.40^{b} \pm 0.89$	$7.20^{a} \pm 0.45$	$6.40^{a} \pm 0.89$	$6.40^{b} \pm 0.55$
FSO	$6.20^{b} \pm 1.30$	$6.60^{a} \pm 0.89$	$6.00^{b} \pm 1.23$	$5.40^{b} \pm 0.55$	$7.00^{b} \pm 0.71$	$5.80^{b} \pm 0.84$	$4.80^{b} \pm 1.30$	$5.20^{c} \pm 0.84$

Significant differences are seen between means in the same row with different superscripts ($p < 0.05$).

Table 4.6: Presents the Sensory Analysis for Instant Extruded Snacks Developed From Maize-Sorghum Based Extrudate.

The Sensory scores of the samples ranged from 5.60 to 8.00 for colour,6.40 to 8.20 for shape, 5.40 to 8.20 for taste, 6.00 to 7.40 for aroma, 7.00 to 8.60 for crispiness, 5.80 to 7.20 for sweetness, 5.40 to 6.60 for after taste, and 6.20 to 8.00 for overall acceptability.

Table 4.6: Sensory Results for Instant Extruded Snacks Developed from Maize-Sorghum Based Extrudate

Sample	Colour	Shape	Taste	Aroma	Crispiness	Sweetness	Aftertaste	Overall Acceptability
GSO	8.00^{a} ± 1.23	8.20^{a} ± 0.84	8.20^{a} ± 0.84	7.40^{a} ± 1.14	8.60^{a} ± 0.55	7.20^{a} ± 0.84	6.60^{a} ± 0.55	8.00^{a} ± 0.71
HSO	7.20^{a} ± 1.10	7.00^{a} ± 1.00	7.40^{a} ± 0.89	6.60^{ab} ± 0.55	7.40^{b} ± 0.89	7.20^{a} ± 0.45	6.40^{ab} ± 0.89	7.00^{ab} ± 1.00
ISO	5.60^{b} ± 0.55	6.40^{b} ± 1.14	5.40^{b} ± 0.55	6.00^{b} ± 0.71	7.00^{b} ± 0.71	5.80^{b} ± 0.84	5.40^{b} ± 0.89	6.20^{b} ± 1.10

Significant differences are seen between means in the same row with different superscripts ($p < 0.05$).

Table 4.7: Sensory Evaluation Result of The Best from Each segment (A,B,C) Base Product On Overall Acceptability:

Sample	Colour	Shape	Taste	Aroma	Crispiness	Sweetness	Aftertaste	Overall Acceptability
ASO	8.50^{a}	6.40^{b}	8.80^{a}	8.60^{a}	7.00^{b}	8.10^{a}	7.80^{a}	8.50^{a}
	± 0.71	± 0.89	± 0.53	± 0.84	± 0.84	± 0.84	± 0.55	± 0.71
DSO	6.80^{b}	7.60^{ab}	7.20^{ab}	6.80^{b}	8.10^{a}	7.80^{ab}	7.00^{ab}	7.00^{b}
	± 0.53	± 0.82	± 0.89	± 0.55	± 0.71	± 0.54	± 0.55	± 0.84
GSO	7.80^{ab}	8.20^{a}	7.80^{a}	7.40^{ab}	8.00^{a}	7.96^{a}	7.40^{a}	8.30^{a}
	± 0.55	± 0.55	± 0.71	± 0.84	± 0.45	± 0.55	± 1.00	± 0.89

Means in the same row having different superscripts are significantly different ($p < 0.05$)

Plate 11: Images of the developed snacks from the Preliminary trials

Plate 12: Images showing the Developed Instant Snacks

Plate 13: Images of the developed Snack

4.8 Discussion of Findings

This study assessed the nutritional and sensory evaluation of instant extruded snacks developed from the blends of malted (yellow maize and white sorghum), Soy beans, sweet potatoes, and brisket bones. The snacks developed was categorized into three samples, where Maize based sample were grouped into three samples namely: ASO (30hrs Malted Maize 70%, Sweet Potato Flour 20%, Soya beans 5%,, Brisket Bone 5%), BSO(30hrs Malted Maize 65% Sweet Potato Flour 20%, Soya beans (10%), Brisket Bone 5%) & CSO(30hrs Malted {Maize (60%) Sweet Potato Flour 20%, & Soya beans (15%), Brisket Bone 5%).

Sorghum based samples were grouped into three samples namely: DSO(20hrs Malted Sorghum (70%), Sweet Potato Flour 20% & Soybeans 5%, Brisket Bone 5%), ESO (20hrs Malted Sorghum (65%), Sweet Potato Flour 20%Soya beans (10%), Brisket Bone 5%), & FSO (20hrs Malted Sorghum (70%), Sweet Potato Flour 20% Soy beans (15%) Brisket Bone 5%).

Maize-Sorghum based samples were also grouped into three samples namely: GSO(30hrs Malted Maize 35% +20hrs sorghum (35%), Sweet Potato Flour 20% & Soya beans (5%)} Brisket Bone 5%), HSO(30hrs Malted Maize 32.5% +20hrs sorghum 32.5%, Sweet Potato Flour 20%, Soya beans 10% Brisket Bone 5%) & ISO(30hrs Malted Maize 30% +20hrs sorghum 30%, Sweet Potato Flour 20%, & Soybeans 15% Brisket Bone 5%).

Based on the proximate analysis conducted on the instant extruded snacks developed from the blends of malted (yellow maize and white sorghum), Soybeans, sweet potatoes, and brisket bones, Moisture contents of all the samples ranged from 4.10% to 4.20% while ash contents ranged between 1.80% to 2.00% respectively. Comparable moisture contents was also obtained in a finding on the development of an extruded snack based on sorghum, Pearl Millet and Bio-fortified beans where the moisture contents of all the samples ranged between 6.22 to 9.70%.[1] To prevent bacterial and mold growth, which shortens the product's shelf life, the moisture content should be less than 18%.[2] the ash content in this finding was in line with a research conducted on the Development of a protein-rich ready-to-eat extruded snack from a composite blend of rice, sorghum and soybean Flour.[3] The snack developed were a good source of protein with values ranging between 12.80% to 14.60% respectively. Protein content was highest in sample the ISO with 14.60%. This might be because of the percentage of soybeans used in the sample. This result is similar to a study conducted on the development and Characterization of extruded fura from mixtures of pearl millet and grain legumes flours which also recorded high protein content[4]. Due to their high protein content (17–34%), pulses can sustainably provide adequate nutrition, particularly when combined with cereal proteins.[5] The fat content in this study was reported to range between 3.10% to 3.15% The fat variations obtained were higher compared to those obtained in a study which ranged between 1.31 and

2.36% on the development of protein-rich sorghum-based expanded snacks using extrusion technology.[6] this could be a result of the fat content in brisket bone. The carbohydrate content in this study aligns with a finding on developing an Extruded Snack Based on Sorghum, Pearl Millet, and Biofortified bean, which recorded a comparable carbohydrate content.[1]

The calcium content reported ranged between 262.20mg/100g to 268.40mg/100g. Calcium is a micronutrient necessary for bone health.[7] A similar study conducted on the Optimisation of Rice-Kidney Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum Flours for the Production of Ready-to-eat Optimisation of Rice Kidney Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum found calcium values ranging between 212 and 280 mg/100 g.[8] In another study on Formulation and nutritional evaluation of multigrain ready-to-eat snack mix from minor cereals, their mean calcium content was 219 mg/100 g which was lower than the calcium content reported in this study.[9]

For the magnesium content, the values range between 137.22mg/100g to 164.22mg/100g. In particular, magnesium supports a healthy neurological system, energy metabolism, and strong bones. The magnesium content obtained was lower compared to values obtained in a study on the Optimisation of Rice-Kidney

Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum Flours for the Production of Ready-to- to-eat extruded snacks.[8]

The sodium and potassium content were highest in the sample ISO, this might due to the potassium content in malted corn. Higher sodium content was recorded in a finding on the Optimisation of Rice-Kidney Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum Flours for the Production of Ready-to-eat extruded snacks. However, low sodium levels are desirable as high intakes are associated with disorders of the circulatory system.

Zinc is an important micronutrient for human health because it has critical structural and functional roles in systems that are involved in gene expression, cell division, growth, immunologic and reproductive functions therefore high but adequate levels are required as per life cycle stage.[1] The zinc content in this study reported a similar result with a findings on the Development of an Extruded Snack Based on Sorghum, Pearl Millet and Biofortified beans. Also, a higher zinc content was recorded in a study on the optimisation of Rice-Kidney Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum Flours for the Production of Ready-to-eat extruded snacks.[1,8]

Phosphorus contents were between 370.23 to 403.23mg/100g respectively for all the samples. This was higher than the phosphorus content in a study on the development of an Extruded Snack Based on Sorghum, Pearl Millet and Biofortified beans.[1] and lower than that obtained in a study on the Development of a Nutritious Composite Flour from Pearl Millet (Pennisetum Glaucum) And Pumpkin Fruit (Cucurbita Pepo-Variety Styriaca) of 1050 mg/100 g.[10]

The iron content obtained was 4.20 to 4.65 mg/100g. Iron insufficiency is common in developing nations among newborns and young children, thus their meals must provide adequate levels of iron. Iron is necessary for children's healthy growth, mental and physical development, and the production of enough hemoglobin. The iron content in this study is higher compared to research on the development of an Extruded Snack Based on Sorghum, Pearl Millet and Biofortified beans where a lower content of iron was reported.[1]

In terms of Vitamins, Vitamin A is a necessary vitamin for human nutrition. It aids in other bodily metabolic processes as well as sight brightness and clear eyesight. In impoverished nations, vitamin A insufficiency is a major contributor to high rates of morbidity and mortality in young children, and nursing mothers.[11] The vitamin A content of the ASO sample (70% 30 hours malted maize + 20% sweet potato + 5% soybeans + brisket bone). The result of this study is similar to the findings on the evaluation of complementary foods produced from sorghum, soybean, and Irish potato composite flours.[12] The vitamin B content in the BSO sample, (65% 30 hours malted maize + 20% sweet potato + 10% soybeans + 5% brisket bone) was observed to increase with the increase in the proportion of soybeans in the blends and this is in agreement with the report that soybeans are a rich source of thiamine.[13] Thiamine sustains a positive outlook in people and aids in the treatment of beriberi.[14]

Furthermore, Pasting characteristics are among the most important parameters used to ascertain the suitability of flours and starches in food products.[15] They have been used to predict the quality of some end-use products such as rice noodles and cooked rice.[16] The highest peak viscosity (808.50) was sample ESO (20hrs Malted Sorghum (65%), Sweet Potato Flour 20%Soya beans (10%), Brisket Bone 5%). The lowest peak viscosity was recorded for sample CSO (30hrs Malted {Maize (60%) Sweet Potato Flour 20%, & Soybeans (15%), Brisket Bone 5%). Peak viscosity, which is reached prior to the structural disintegration of inflated starch granules, represents the flour suspension's ability to hold water.[17]

The trough viscosity of the samples ranged from 413.00 to 616.50RVU. The lowest trough viscosity was recorded for sample FSO (413.00), whereas the highest was recorded for sample ASO (616.50).

Breakdown viscosity illustrates the flour suspension's capacity to tolerate high temperatures under continuous shear circumstances.[17] Breakdown viscosity of flour samples was found in the range of 45.00 to 373.00RVU. High Breakdown viscosity is desirable for the production of snacks.[18]

Final viscosity indicates the ability of the flour to form a viscous paste after cooking and cooling and was found in the range of 967.50 to 1437.50RVU. The lowest final viscosity was recorded in the sample FSO (936.50) possibly because of its high damaged starch content which has a low tendency to develop viscous pastes. At the same time, highest Final viscosity of potato flour can be attributed to its highest starch content (1437.50) and large-sized starch granules.[17]

Setback viscosity, which denotes the tendency of cooked starchy material to re-associate and retrograde upon cooling (Hussain et al., 2014),[17] ranged from (523.50 to 821.00RVU) for all samples. Lower Setback viscosity was recorded for sample (FSO). However, the higher Setback viscosity of sample ASO (821.00) indicates its high retro gradation tendency and ability to form a cohesive gel upon cooling.[19] The peak time of flour samples indicates the time required to reach the peak in viscosity and ease of cooking a particular sample. The peak time of flour samples ranged from 4.67 to 7.00mins. The minimum peak time of 4.67 min was recorded for sample FSO and the highest (7.00 min) for sample ASO,BSO, CSO respectively. 80.35 to 85.63$^{0}{}_{C}$ was recorded for pasting temperature, the maximum pasting temperature was the sample BSO (83.98).the minimum was sample FSO (80.35). The result of this study aligns on a finding on the Effect of seven non-conventional starch rich sources on physico-chemical and sensory characteristics of extruded snacks.[19]

In terms of sensory evaluation, 7.40 ESO to 8.00DSO was recorded for colour in Maize Based snacks, sample DSO was recorded with the highest visual scores. The higher the comparatively bright colour of malted corn snacks in the sample and the desirable colour of corn-based snacks could be the possible reasons for their high visual scores.[19]

Mouthfeel, described as a sensation recognized by the nervous system in the cavity of the mouth ,[20] the taste was found in a range of 8.80-6.20 with the highest value after taste of 7.40 was recorded in sample ASO. Sorghum based snack was recorded with the highest taste and after taste score followed by the maize sorghum based snacks in the sample GSO corn-based snacks while the least for after taste scores were recorded for maize-sorghum in the sample FSO. The highest mouthfeel score of presence of an appreciable amount of soluble sugars in corn was the possible reason for the high mouth-feel score of Maize-sorghum based snacks.[21] Appearance implies the visual characteristics of the extruded product including its shape.[20] The highest score for shape was recorded in snacks developed from Maize based and maize-sorghum based snacks in the sample ASO and GSO respectively. While sample ISO in maize-sorghum based snacks recorded the lowest score for shape.

Maize based snacks recorded a high score of sweetness in the sample ASO (8.60) while high score was recorded for crispness in sample DSO and GSO respectively.

The high score for sweetness in sample ASO could be as a result of the increase proportion of sweet potato flour.

Overall acceptability of all the samples ranged from 8.50, 8.30, & 7.00 respectively. The sample ASO from maize based snacks was found to be highly acceptable with an overall acceptability score of 8.50 followed by GSO from maize-sorghum based snacks (8.30) while the least overall acceptability score was recorded for sample DSO from sorghum based snacks (7.00). Overall acceptability was determined as the average value of all the sensory characteristics.[22]

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Chapter Five

Conclusion

5.1 Summary of Findings

This study was develop to assess the nutritional and sensory evaluation of instant extruded snacks developed from the blends of malted (yellow maize and white sorghum), Soy beans, sweet potatoes, and brisket bones. The snacks developed was categorized into three samples, where Maize based sample were grouped into three samples namely: ASO (30hrs Malted Maize 70%, Sweet Potato Flour 20%, Soya beans 5%,, Brisket Bone 5%), BSO(30hrs Malted Maize 65% Sweet Potato Flour 20%, Soya beans (10%), Brisket Bone 5%) & CSO(30hrs Malted {Maize (60%) Sweet Potato Flour 20%, & Soya beans (15%), Brisket Bone 5%).

Sorghum based samples were grouped into three samples namely: DSO(20hrs Malted Sorghum (70%), Sweet Potato Flour 20% & Soybeans 5%, Brisket Bone 5%), ESO (20hrs Malted Sorghum (65%), Sweet Potato Flour 20%Soya beans (10%), Brisket Bone 5%), & FSO (20hrs Malted Sorghum (70%), Sweet Potato Flour 20% Soy beans (15%) Brisket Bone 5%).

Maize-Sorghum based samples were also grouped into three samples namely: GSO(30hrs Malted Maize 35% +20hrs sorghum (35%), Sweet Potato Flour 20% & Soya beans (5%)} Brisket Bone 5%), HSO(30hrs Malted Maize 32.5% +20hrs sorghum 32.5%, Sweet Potato Flour 20%, Soya beans 10% Brisket Bone 5%) & ISO(30hrs Malted Maize 30% +20hrs sorghum 30%, Sweet Potato Flour 20%, & Soybeans 15% Brisket Bone 5%).

The proximate composition of the samples ranged from 3.10% to 3.20% for moisture content, 6.80% to 7.50% for ash, 10.29% to 10.58% for fibre, 11.80% to 13.60% for crude protein, 3.10% to 3.15% for fat and 65.08% to 66.32% for carbohydrate, and 338.34kcal to 331.37kcal for Energy.

The micronutrients composition of the samples ranged from 262.20mg/100g to 268.40mg/100g for Calcium, 137.22mg/100g to 164.22mg/100g for Magnesium, 455.23 to 458.35mg /100g for Potassium,120.00 to145.45mg/100g for Sodium, 370.23 to 403.23mg/100g for Potassium,40.20 to 49.65 mg/100g for Iron ,1.11 to 3.23mg/100g for Zinc, 3.43 to 4.56mg/100g for Vitamin A,3.76 to 4.34mg/100g for Vitamin B1 and 0.69 to 0.76mg/100g.

The pasting properties of composition flour blends samples ranged from 539.00 to 808.50RVU for peak viscosity, 413.00 to 616.50RVU for Trough, 45.00 to 373.00RVU for breakdown, 967.50 to 1437.50RVU for final viscosity, 523.50 to

821.00RVU for setback,4.67 to 7.00mins for peak time , 80.35 to 85.63^{0}C for pasting temperature.

The Sensory scores of the Maize based snacks samples ranged from 7.40 to 8.00 for colour,7.40to8.20 for shape, 6.40 to 8.80 for taste, 7.20 t0 8.20 for aroma, 7.00 to 7.60 for crispiness, 6.00 t0 8.60 for sweetness, 6.00 to 7.40 for after taste, 6.40 to 8.80 for overall acceptability.

The Sensory scores of the Maize-sorghum based snacks samples ranged from 6.00 to 8.20 for colour,6.60 to 7.80 for shape, 6.00 to 7.80 for taste, 5.40 to 6.60 for aroma, 7.00 to 8.60 for crispiness, 5.80 to 7.20 for sweetness, 4.80 to 6.60 for after taste, and 5.20 to 8.00 for overall acceptability.

The Sensory scores of the sorghum based snacks samples ranged from 5.60 to 8.00 for colour,6.40 to 8.20 for shape, 5.40 to 8.20 for taste, 6.00 to 7.40 for aroma, 7.00 to 8.60 for crispiness, 5.80 to 7.20 for sweetness, 5.40 to 6.60 for after taste, and 6.20 to 8.00 for overall acceptability.

The best Sensory scores of the samples from each segment ranged from 6.80 to 8.50 for colour,6.40 to 8.20 for shape, 7.20 to 8.80 for taste, 6.80 to 8.60 for aroma,7.00 to 8.10 for crispiness, 7.80 to 8.10 for sweetness, 7.00 to 7.80 for after taste, and 7.00 to 8.50 for overall acceptability.

5.2 Conclusion

Based on the research combining malted maize, malted sorghum, soybean, sweet potato, and brisket bone to develop an instant extruded snack, the following conclusion can be drawn:

An instant extruded snack that is high in fibre, macronutrients, and vital micronutrients like calcium, magnesium, potassium, zinc, and iron was successfully created by the study. The snack's nutritional profile was greatly improved with the addition of sweet potato, brisket bone, malted grains, and legumes. The product demonstrated high levels of protein, dietary fiber, and essential minerals, making it a valuable addition to the diet for improving overall nutritional intake.

Sensory evaluation indicated that the extruded snack was well-accepted in terms of taste, texture, color, and overall acceptability. The combination of ingredients not only provided a balanced nutritional profile but also maintained desirable sensory attributes, ensuring consumer satisfaction. In conclusion, the developed instant extruded snack holds promise as a nutritious and sensory-acceptable food product that can contribute to addressing nutritional deficiencies and promoting better health outcomes. Further research and development could focus on optimizing the formulation and processing conditions to enhance the product's marketability and consumer appeal.

5.3 Recommendation

commonly consumed nutrient dense instant extruded snack could be developed from blends of maize, sorghum, soybeans, sweet potato and brisket bone and can be a vehicle to combat malnutrition and some notable nutritionally non-communicable diseases.

As targeted by this work, Snack or meal that is rich in Beta carotene, Protein, Calcium, Fibre, and low in sugar. Micronutrients could help in lowering the incidence of diet-related non-communicable diseases such overweight, obesity, diabetes, and cardiovascular disorders as well as preventing the prevalence of malnutrition and can also be adopted as part of school feeding program, to contribute to the dietary intake of school aged Children.

In summary, the recommendations involve a strategic focus on maize-based formulations, highlighting specific successful formulations like "ASO," exploring improvements in sorghum-based snacks, optimizing maize and sorghum combinations, and considering factors influencing crispiness and sensory preferences in the development and marketing of extruded puffy Moreso, The comprehensive macro- and micronutrient analysis sheds important light on the dietary composition of the manufactured instant extruded snacks., offering a foundation for potential improvements or optimizations in the formulations snacks. Overall, the choice of extrudate should be based on the desired nutritional profile, taste preferences, and dietary goals.

5.4 Contribution to knowledge

By developing instant extruded snacks from composite blends of sweet potato, brisket bone, yellow maize, and sorghum, the study makes a contribution. The food sector may be impacted by this creative approach to snack manufacture, which offers substitute and possibly healthier snack options.

The study's usage of malted grains and the transformation of different ingredients into flours contribute to our knowledge of how processing methods can affect the properties of the finished product. For food scientists and producers trying to optimize processes for comparable items, this knowledge may be very helpful.

Important details regarding the nutritional value of the designed snacks are provided by the assessment of their nutritional attributes and approximate composition. Policymakers, dietitians, and consumers who want to encourage better eating options will find this data to be helpful.

The functional characteristics of the ingredients and their behavior during the extrusion process are better-understood. For process optimization and product quality control, this information might be extremely important.

The sensory assessment reveals information about the acceptance and preferences of consumers. Knowing which formulas are more popular can help direct future marketing campaigns and product development

5.5 Suggested Area for Research

Examine how various malting times affect the characteristics of extruded snacks. Examine how different ingredients (sweet potatoes, brisket bones, yellow maize and sorghum) affect the extrusion process and the properties of the finished products. Examine and contrast the proximate compositions (moisture, fibre ash, fat, crude protein, carbohydrate, and energy), of the flour blends

Investigate the levels of micronutrients (Calcium, Magnesium, Potassium, Sodium, Iron, Zinc, Vitamin A, Vitamin B1) in the extrudates and assess their significance for dietary intake.

Optimizations is necessary to take into account ways to improve the sensory appeal and nutritional value of the formulation and examine the possibility of adopting the developed instant extruded snacks by the food industry.

Analyse the market potential for the developed instant extruded snacks as well as consumer preferences for various bases and also examine possible marketing approaches that capitalize on the nutritional advantages and sensory preferences.

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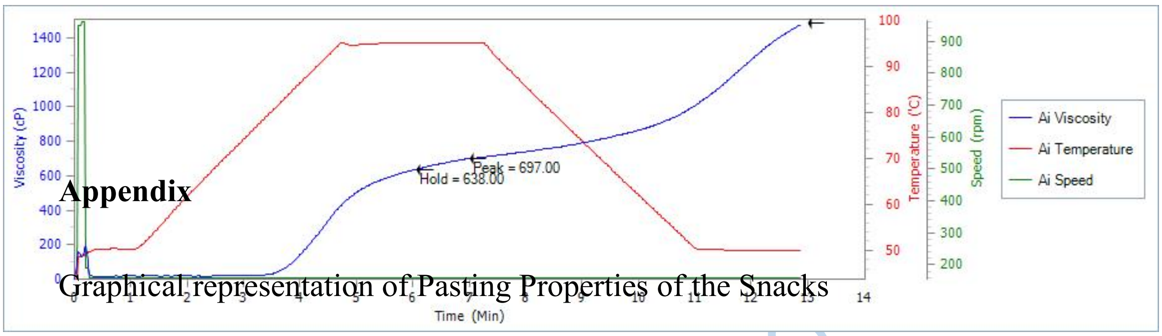
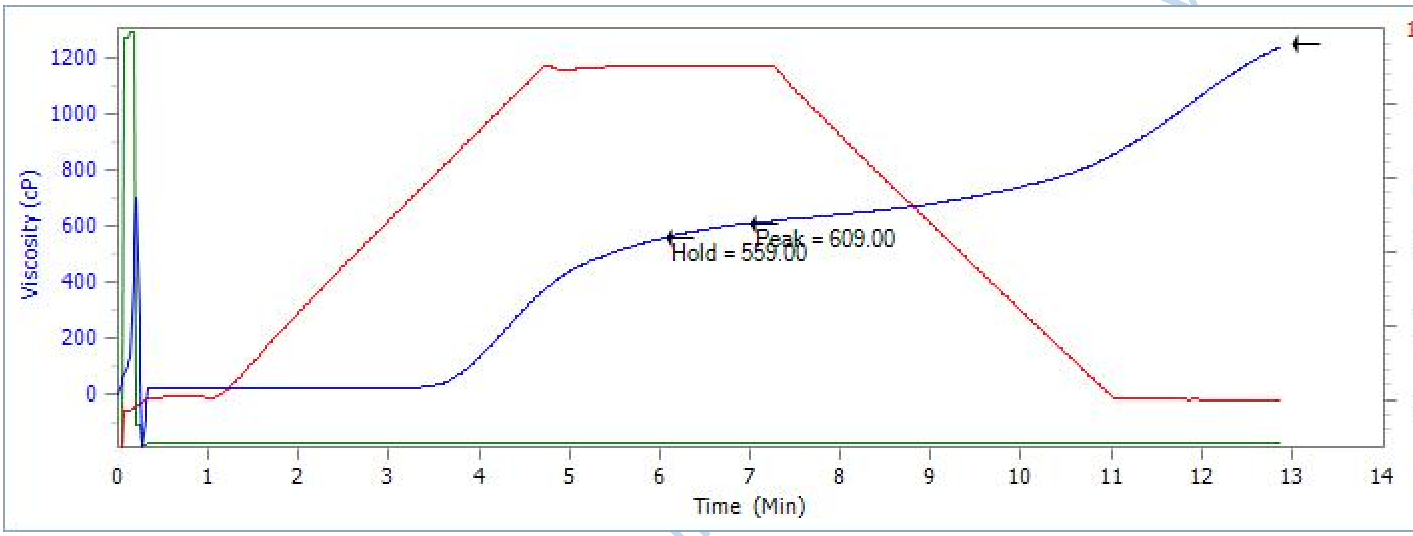
Appendix



Graphical representation of Pasting Properties of the Snacks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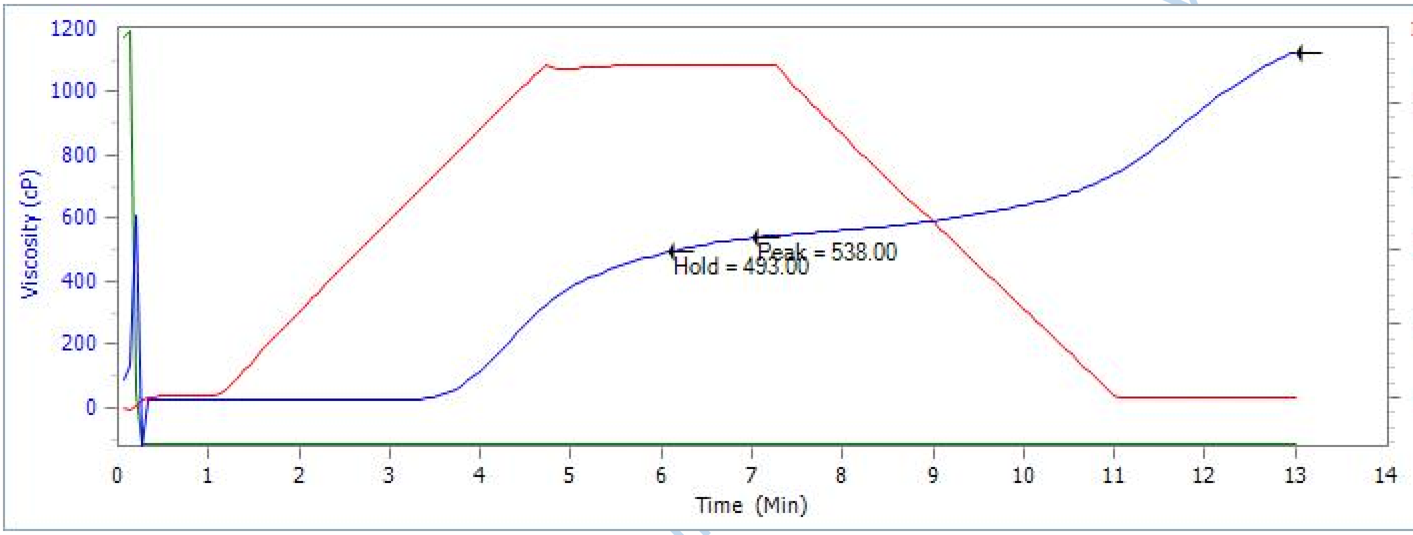
Time (Min)



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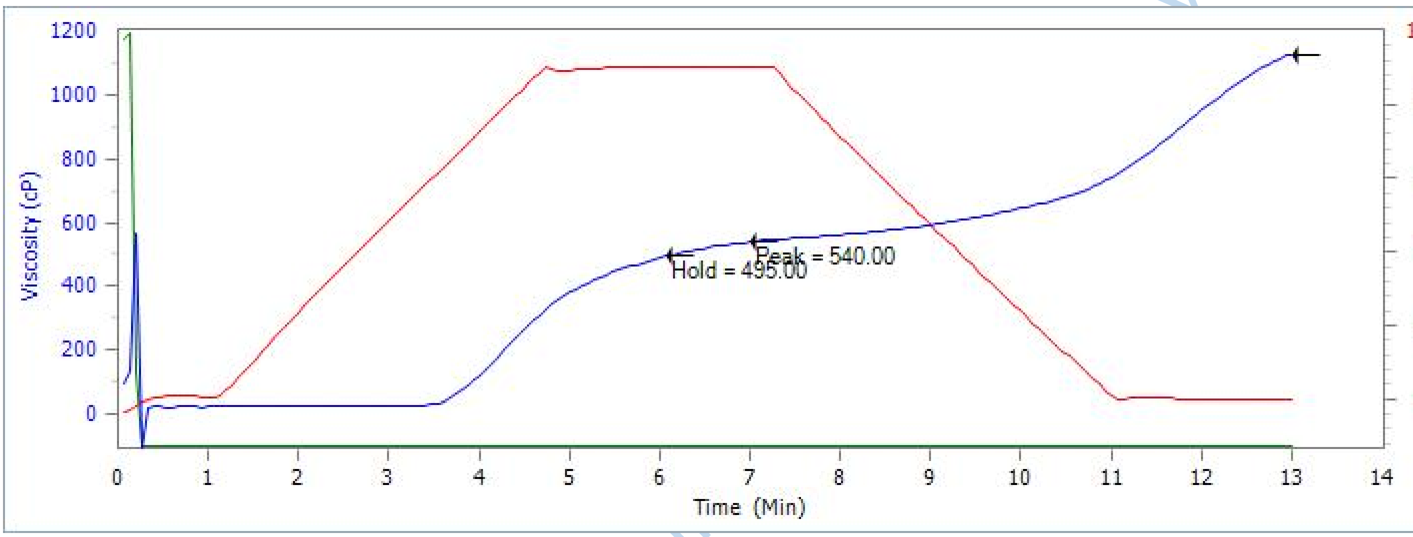
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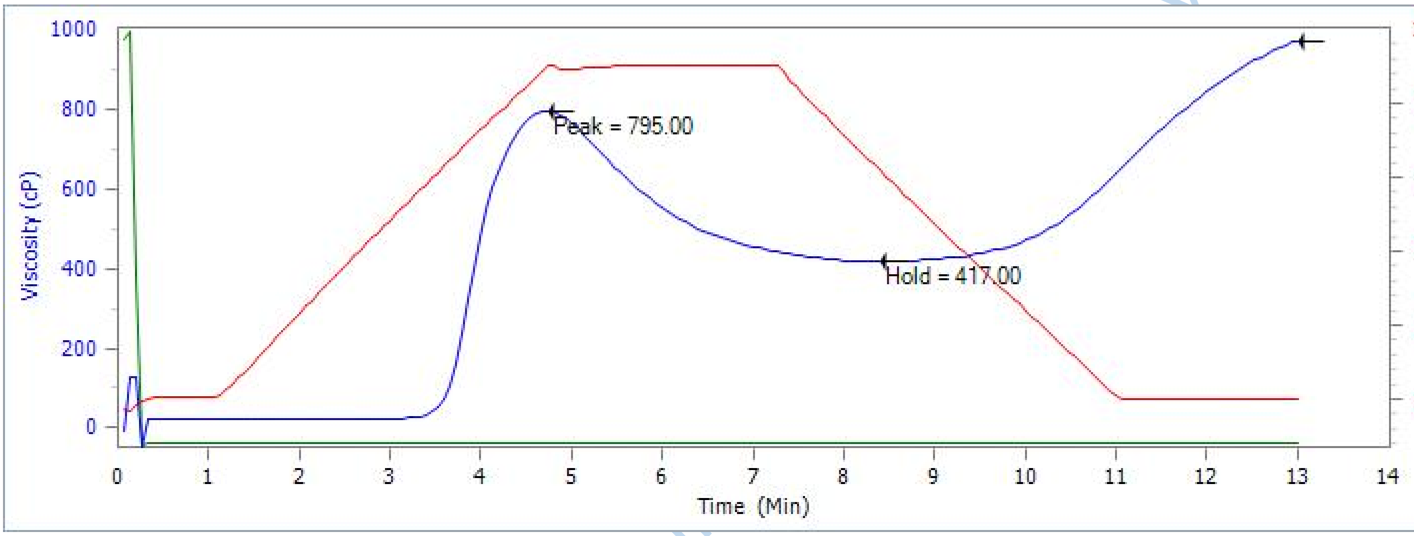
Time (Min)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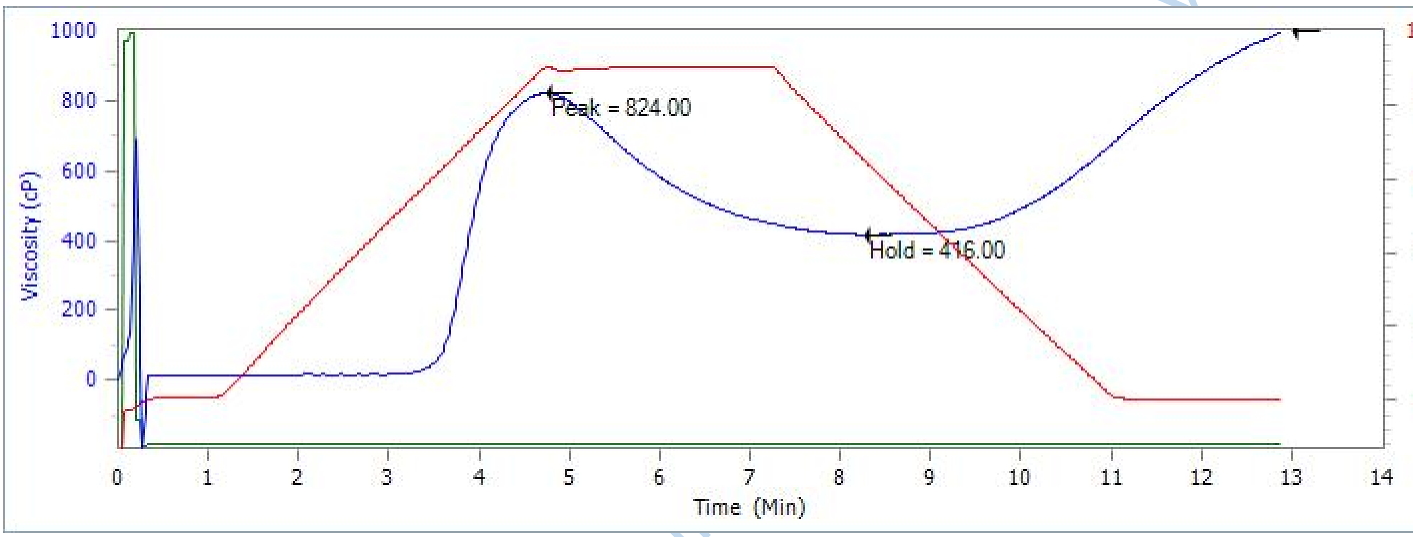

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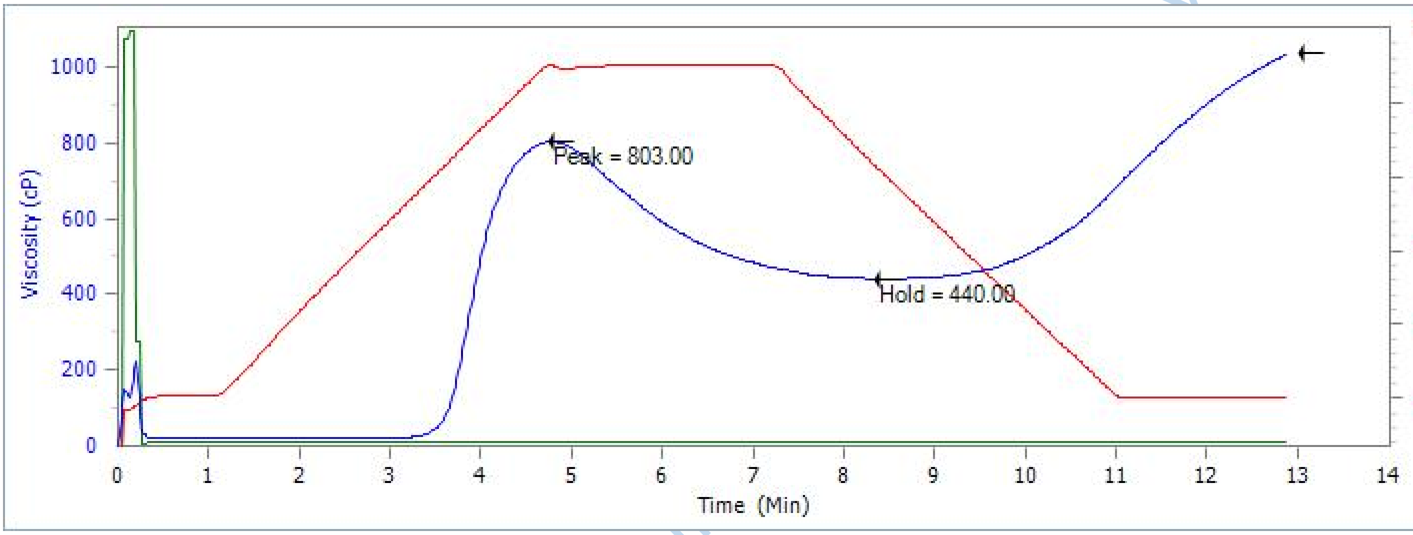
Time (Min)



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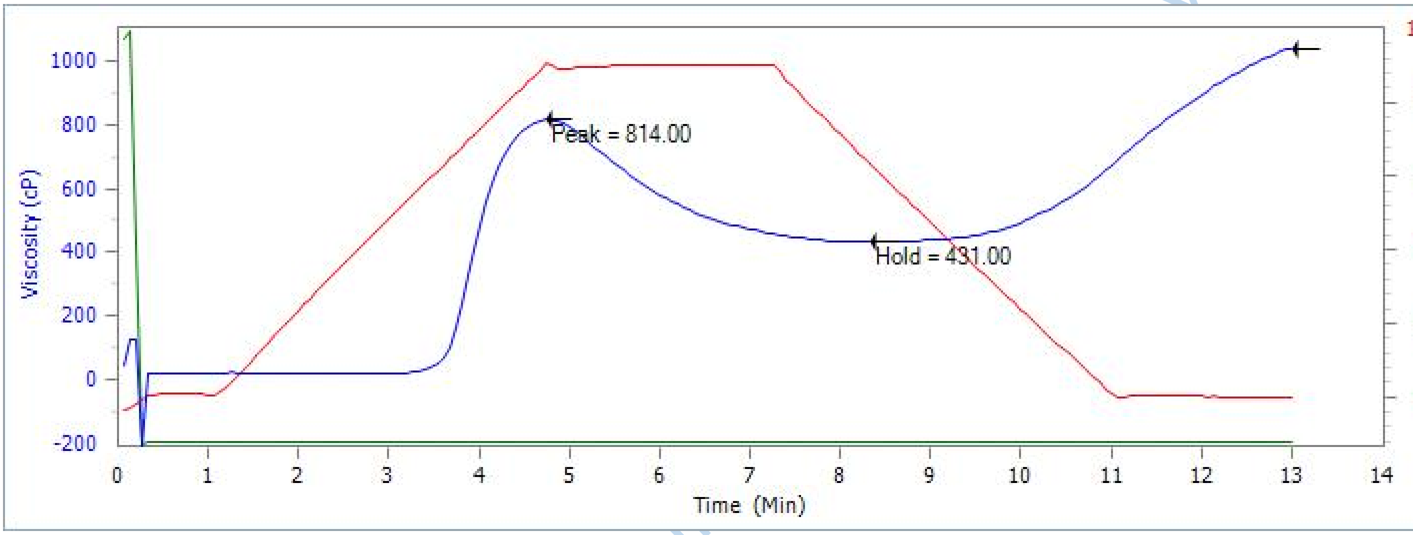

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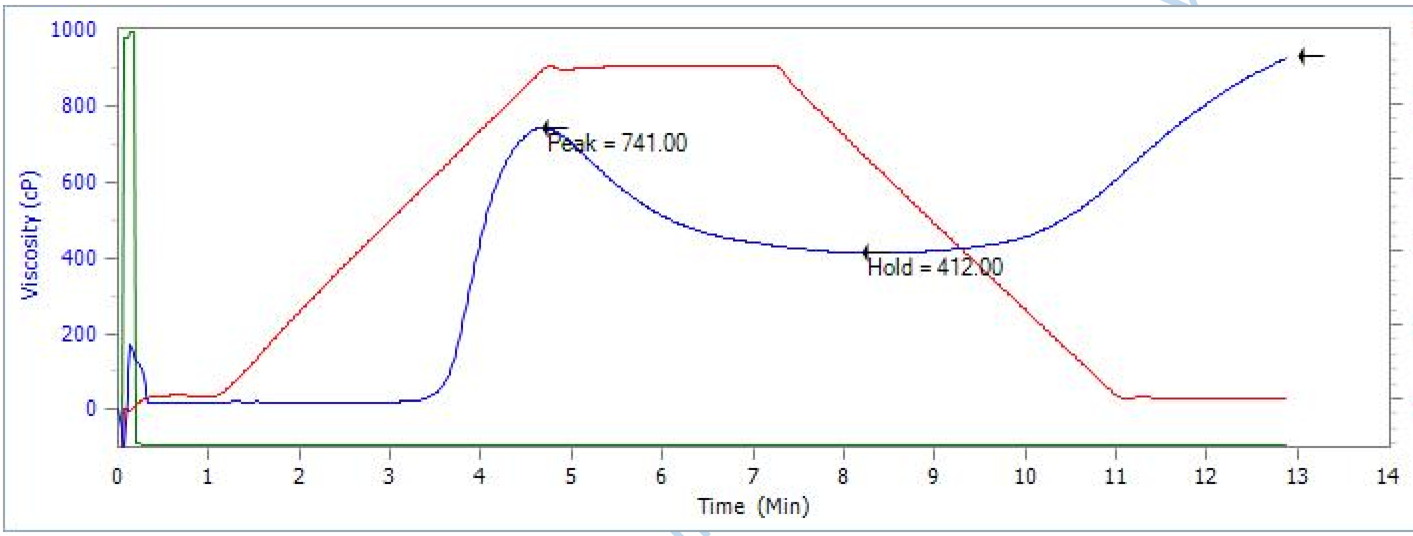

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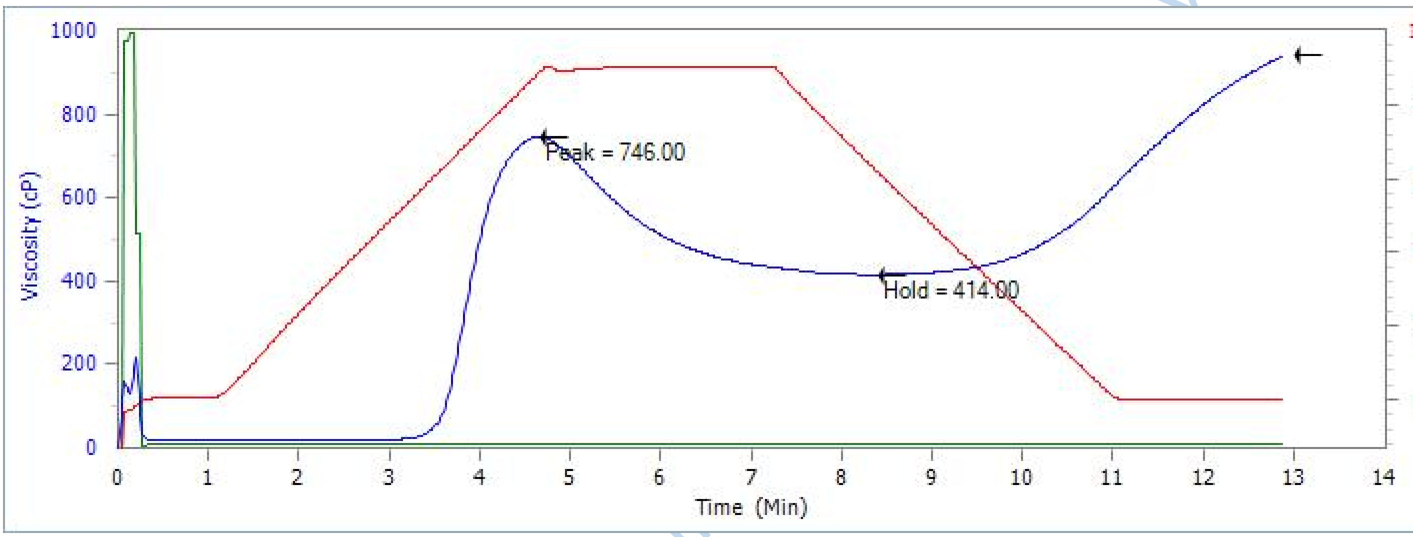

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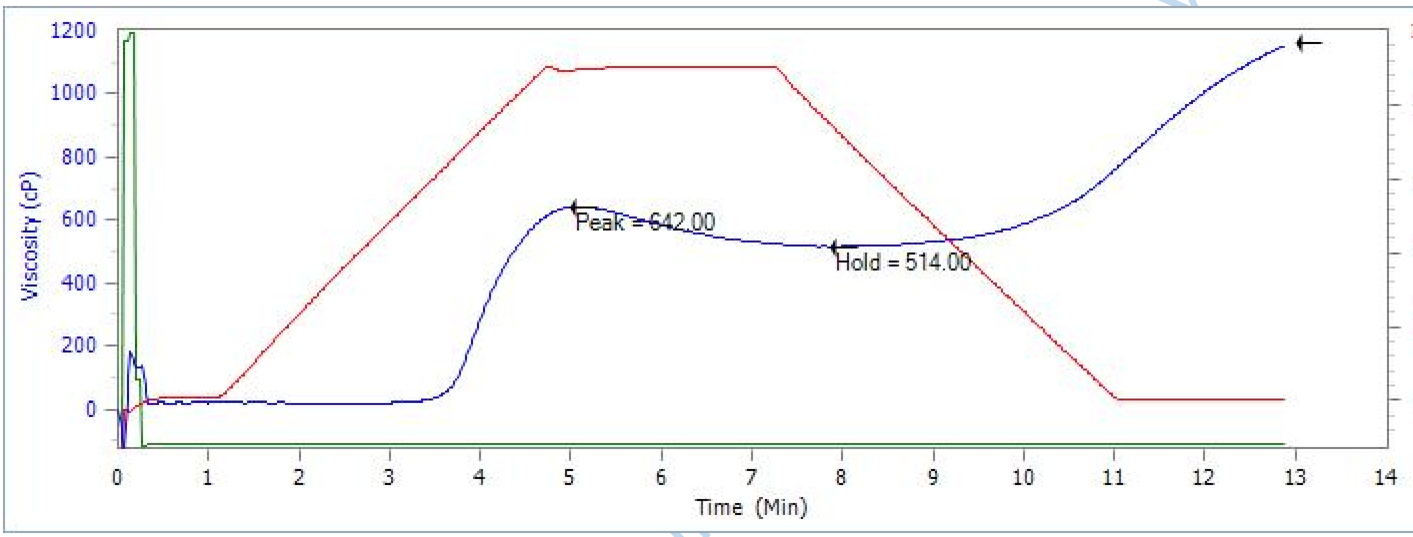

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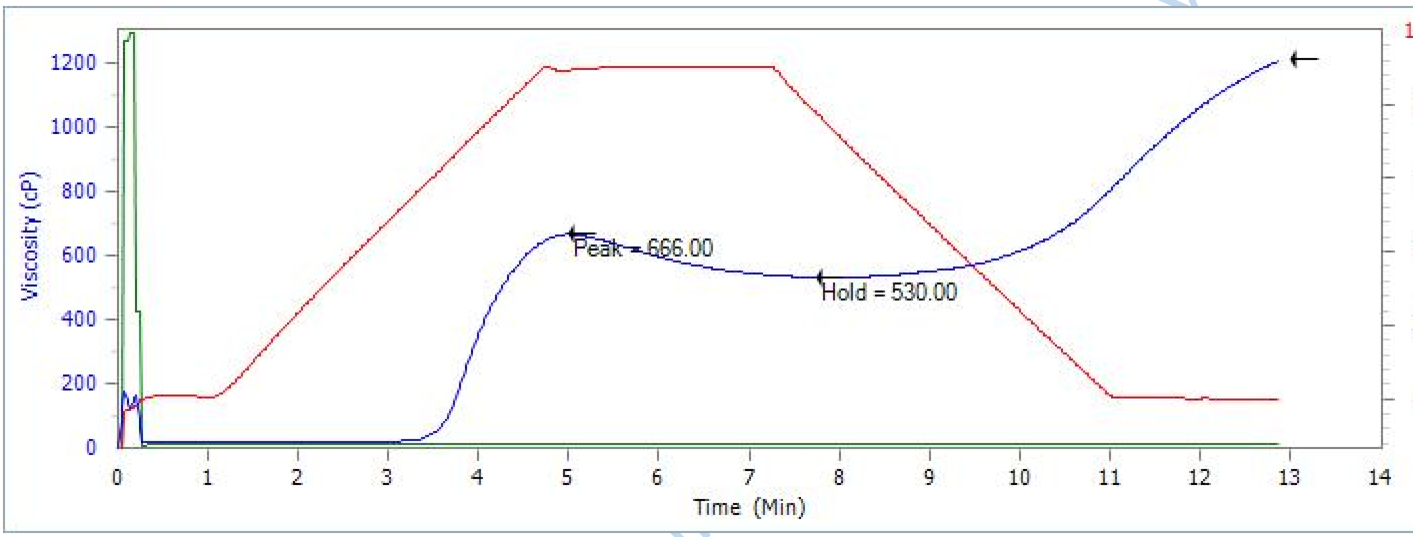

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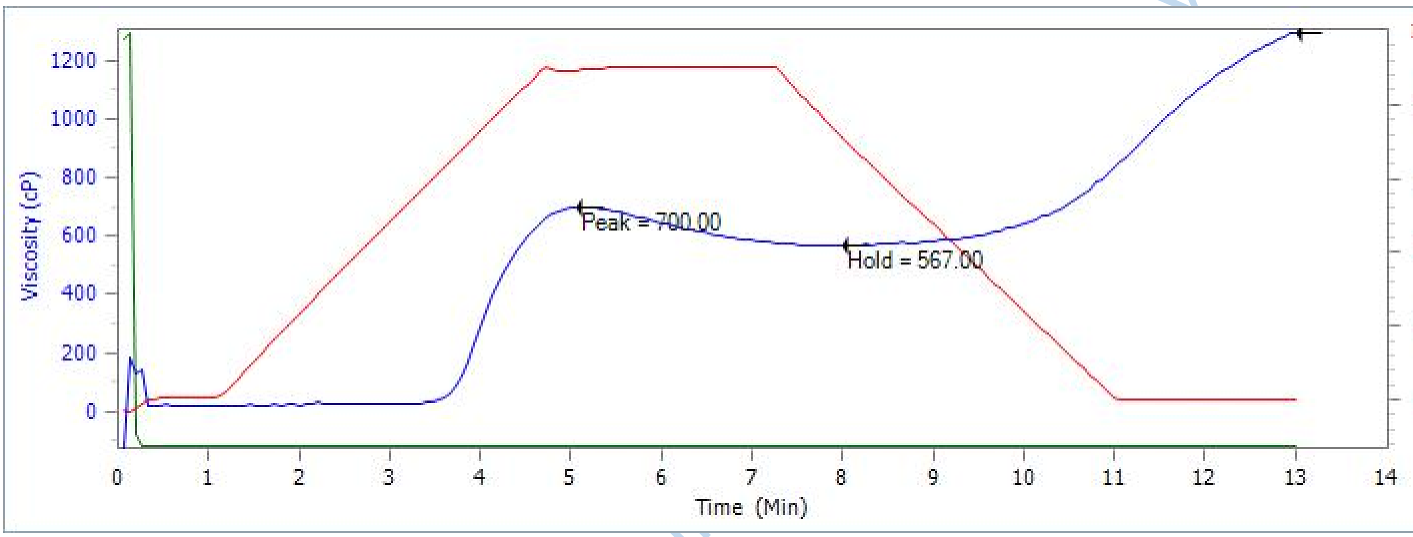
Time (Min)



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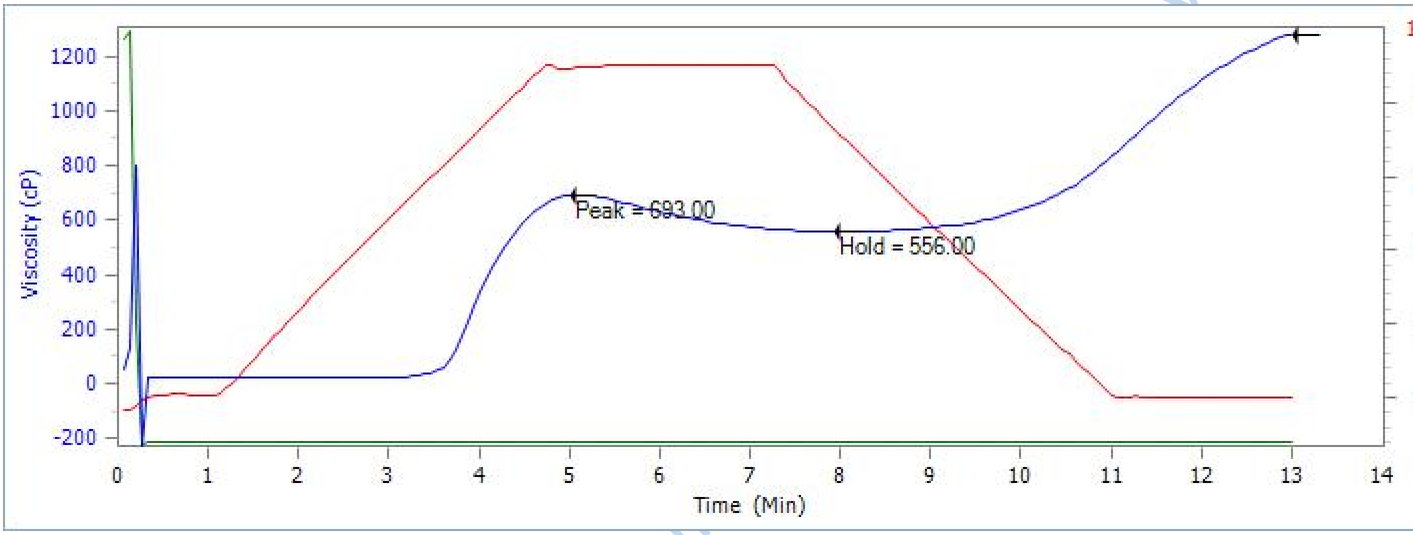
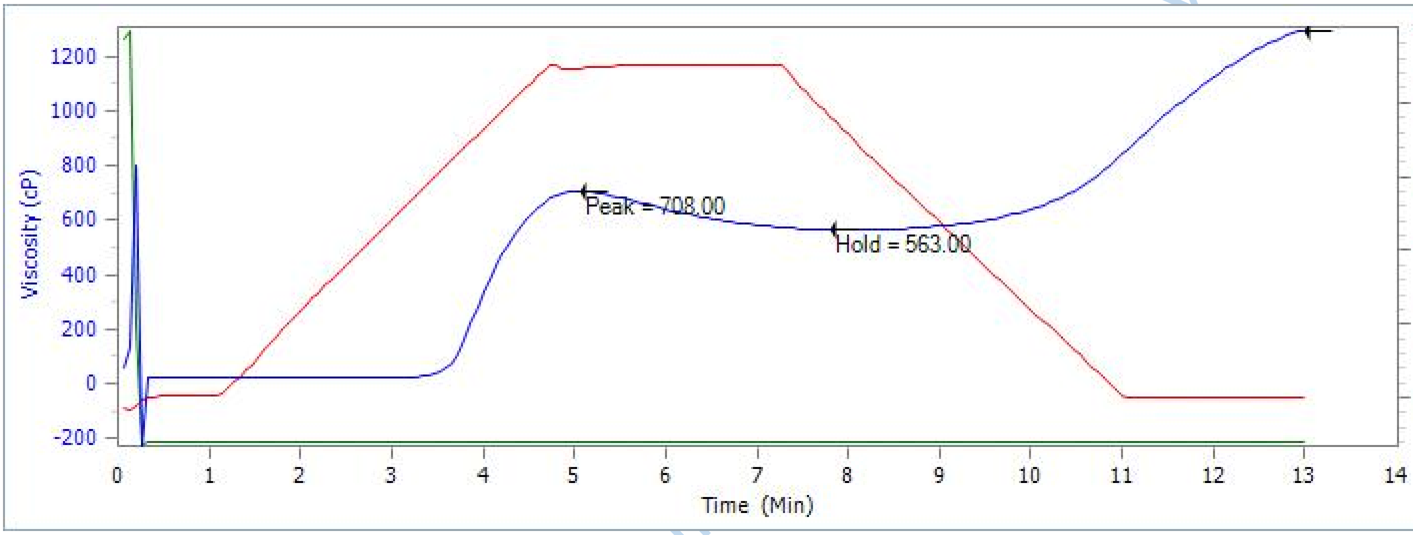
11
12
13
14
Time (Min)



Viscosity (cP)
1200
1000
800
600
400
200
0
-200
Peak = 693.00
Hold = 556.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Time (Min)



Viscosity (cP)
1200
1000
800
600
400
200
0
-200
Peak = 708.00
Hold = 563.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Time (Min)

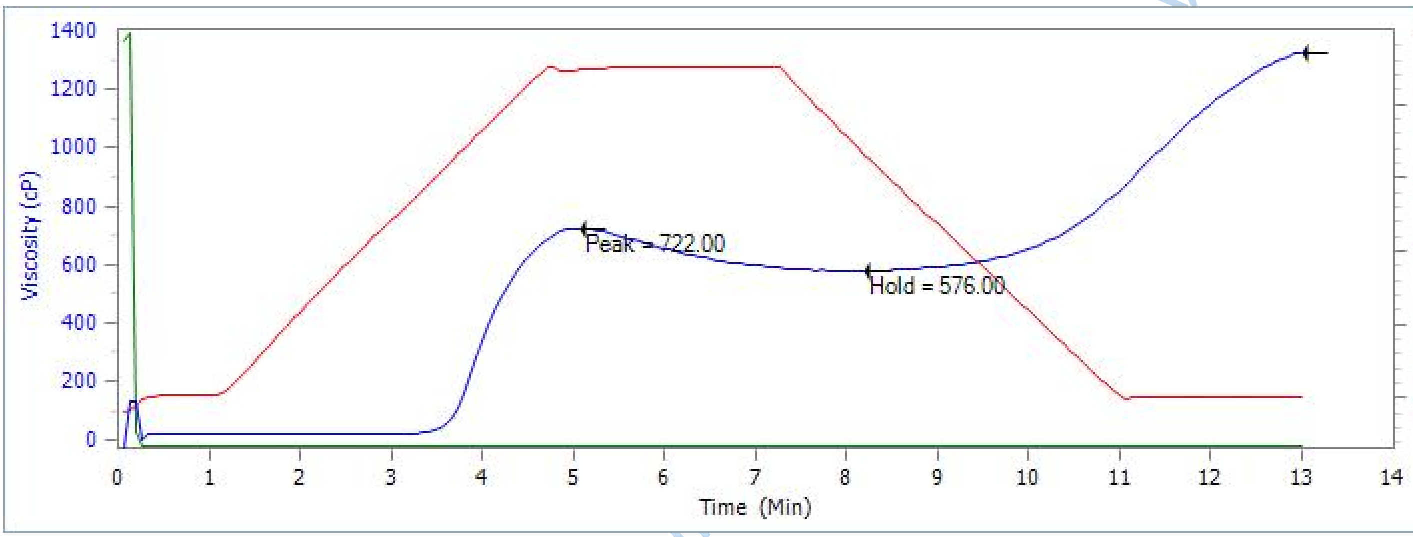

1400
1200
1000
800
600
400
200
0
Viscosity (cP)
Peak = 722.00
Hold = 576.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Time (Min)

Plate 14: Image showing the cooling of the snacks after extrusion

Plate 15: Images showing the crushing of the snacks.

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Plate 16: Image showing Sprouted Sorghum after 20hrs before drying

Plate 17: Image Showing Sprouted Maize

ETHICAL APPROVAL

3. I will ensure that all co-investigator and other personnel assisting in the conduct of this research study have been provided a copy of the entire current version of the research protocol and are fully informed of the current (a) study procedures (including procedure modifications); (b) informed consent requirements and process; (c) potential risks associated with the study participation and the steps required to be taken to prevent or minimize these potential risks; (d) adverse events reporting requirements; (e) data and record-keeping; and (f) the current REC approval status of the research study.

4. I will respond promptly to all requests for information or materials solicited by the REC or REC Office.

5. I will submit the research study in a timely manner for the REC renewal approval.

6. I will not enroll any individual into this research study until such time I obtain his/her written informed consent, or if applicable, the written informed consent of his/her authorized representative (i.e unless the REC has granted a waiver of the requirement to obtain informed consent).

7. I will employ and oversee an informed consent process that ensures that potential research subjects understand fully the purpose of the research study, the nature of the research procedures they are being asked to undergo, the potential risks of these research procedures, and their rights as a research study volunteer.

8. I will ensure that the research subjects are kept fully informed of any new information that may affect their willingness to continue to participate in the research study.

9. I will maintain adequate, current, and accurate records of research data, outcomes, and adverse events to permit an ongoing assessment of the risks/benefits ratio of research study participation.

10. I am cognizant of, and will comply with, current federal regulations and REC requirements governing human subject research including adverse event reporting requirements.

11. I will make a reasonable effort to ensure that subjects who have suffered adverse event associated with research participation receive adequate care to correct or alleviate the consequences of the adverse event in the extent possible.

12. I will ensure that the conduct of this research study adheres to Good Clinical Practice guidelines.

Mr Owolabi Samuel

Principal Investigator's Name

....

Principal Investigator's Signature and Date

Questionnaire for sensory evaluation

You are presented with samples of instant cereal meals to taste and evaluate. Please indicate your degree of acceptance of the Meal samples by writing the number on the scale that best described your genuine opinion about each of the samples for the attributes tested below

SCALE

9. Extremely acceptable
8. Very acceptable
7. Moderately acceptable
6. Slightly acceptable
5. Neither acceptable nor unacceptable
4. Slightly unacceptable
3. Moderately unacceptable
2. Very unacceptable
1. Extremely unacceptable

SAMPLE CODES ⇒ ☐ ☐ ☐ ☐

ATTRIBUTES

Colour	______	______	______	______
Shape	______	______	______	______
Aroma	______	______	______	______
Crispiness	______	______	______	______
Sweetness	______	______	______	______
After taste	______	______	______	______
Overall Acceptability	______	______	______	______

Ranking ☐ ☐ ☐ ☐

General comments……………………………………………………………

INFORMED CONSENT

TITLE OF THE STUDY

NUTRITIONAL AND SENSORY EVALUATION OF INSTANT SNACK DEVELOPED FROM BLENDS OF MALTED (YELLOW MAIZE, WHITE SORGHUM, SOYABEANS), SWEET POTATO, AND BRISKET BONES.

OWOLABI, Samuel. O

PUBLIC HEALTH DEPARTMENT, LEAD CITY UNIVERSITY

LEAD CITY UNIVERSITY TOLL GATE, IBADAN.

+2348028466411

Owolabisamy4@gmail.com

Purpose of Study

My name is Owolabi Samuel O, and I attend Lead City University in Ibadan, Oyo State, as a master's student studying human nutrition and dietetics at the faculty of basic medical and applied sciences. Nigeria. My research focuses on the nutritional and sensory assessment of instant-extruded snacks made from a combination of malted beans, sweet potatoes, brisket bones, and white sorghum (yellow maize).

I am requesting your assistance in answering this questionnaire as I am interested in assessing the acceptability profiles and sensory attributes of the quick extruded snacks created utilizing a 9-point hedonic scale.

Research Procedure

You will have to respond to private inquiries on the aforementioned study objective if you agree to take part in the research. These inquiries will be made via a methodical questionnaire. The questionnaire will take five to ten minutes to complete.

Risks and Benefits

Participating in the study carries no known risks. Additionally, there are no incentives, but the data you offer should be a valuable contribution to initiatives that strive to enhance the use of grains in the production of cereals.

Compensation

The study participant will not receive payment for their involvement. It is optional to participate.

Confidentiality

Your submission of any information will be kept private and used exclusively for research. Your name won't be needed and won't ever be linked to any information you provide. There will be no collection of personally identifiable information from your response; it is entirely anonymous. The researcher will do everything in their power to protect your privacy. The completed questionnaires will only be accessible to the research team. Privacy and confidentiality will be upheld.

Contact Information

Contact the researcher (information on the first page) with any questions you may have about this study or whether or not participating will negatively affect you. If you believe that you are unable to raise any concerns with the lead investigator or if you have any questions regarding your rights as a research participant, please email the supervisor at ogundele.abimbola@lcu.edu, ng.

Voluntary participation

Your choice to take part in this research is entirely up to you. Whether or not to take art in this course is entirely up to you. Should you choose to participate in this research, a consent form will need to be signed. You are still able to withdraw your consent at any moment and for any reason once you sign the consent form.

Retraction of Authorization/Withdrawal from the Study

Should you want to take part in this research, you are free to stop at any time without incurring any fees. If you decide to withdraw from this study, it won't have an impact on your relationship—if any—with the researcher. Your data will be erased or returned to you if you leave the research before all data collection is finished.

Consent

I've had time to review the material provided, understand it, and formulate inquiries. I understand that my participation is entirely optional and that I can stop at any time, for any reason, and without incurring any fees. I voluntarily consent to taking part in this study and understand that a copy of this consent form will be sent to me.

Participants signature---------------------------------- Date --

Investigators signature-------------------------------- Date--

Biodata

OWOLABI SAMUEL OLUSINA

48 Behind Divine Grace School, Ope-Oluwa CDA Ilepa Ifo, Ogun State

Email:

PERSONAL DATA

Name; Samuel Olusina OWOLABI

Address: 48 Behind Divine Grace School, Ope-Oluwa CDA Ilepa Ifo, Ogun State

Phone number & Email ; 08026466411, 08061746090, owolabisamy4@gmail.com

Nationality: Nigerian

State of Origin: Ogun

Local Government: Egbado South

Date of Birth: 25th September, 1974

Marital Status: Married

Name of next of kin: Atinuke Olajumoke OWOLABI

Address: 48 Behind Divine Grace School, Ope-Oluwa CDA Ilepa Ifo, Ogun State

EDUCATION AND QUALIFICATIONS

Lead City University Ibadan . 2021 – In view

MSc. Human Nutrition and Dietetics.

Federal University of Agriculture Abeokuta 2017

B.Sc. Nutrition and Dietetics

Lagos State Polytechnics, Isolo, Lagos 2002

HND , Food Science and Technology

Federal Polytechnic Ilaro 1998

ND, Food Science and Technology

West African Senior School Certificate (Nov/Dec.) 1996

Work Experience With Dates

Federal Institute of Industrial Research Oshodi [FIIRO] 2009 till date

Food Technology Department, as Chief Research Technologist

Unique Pharmaceutical Ltd, Sango -Ota Ogun State, Nigeria, 2008 2

Production Supervisor, in Infusion Section

Veepee Industry Limited, Sango-Ota Ogun State, Nigeria, 2007

Quality Assurance Officer. In Quality Control Department

Famex Meyer Limited Sango-Ota Ogun State, Nigeria 2003 to Jan.2007

Production Supervisor in Tableting and Liquid Section

Publications and Proceedings

- Owolabi Samuel Olusina, Abodunrin Josephine Olabisi, Ganiyu Akeem Adewale,Mosimabale Margaret Meka, 2024. Chemical and Sensory evaluation of Chin-Chin and Biscuit Developed from Blend of Rice and Cowpea, Research Journal of Food Science and Quality Control, Vol.10. No.5.www.iiardjournals.org.

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- OLUWOLE O.B., Kosoko S.B., Owolabi S.O., Adeyoju, A.O., Bankole, A.O., Ozumba A.U. and Elemo, G.N. (2012): Development and production of high protein and energy density beverages from blends of maize (*Zea mays*), sorghum (*Sorghum bicolor*) and soybeans (*Glycine max*) for school aged children: Effect of malting period on selected proximate parameters and sensory qualities of developed beverages. International Journal of Applied Science and Technology. 2(7): 285-292.

- Oluwole O.B., Kosoko S.B., Owolabi S.O., Salami, M.J., Elemo, G.N. and Olatope S.O.A. (2012): Development and Production of Fermented Flour from

Sweet Potato (*Ipomea Batatas* L.) as a Potential Food Security Product. Journal of Food Science and Engineering. 2: 257-262.

- Kosoko S.B., Oluwole O.B., Okafor O.Y., Elemo G.N., Daramola, A.O., Owolabi, S.O., Aderele, A.A. and Komolafe, A.O. (2011): Utilization Potentials of Cassava starch (*Manihot esculenta*) as Micro-Livestock Feed binder. Asian Journal of Agricultural Research. 5(5):260-268.

- Oluwatoyin Bolanle Oluwole, Owolabi Samuel, Odediran Olajumoke and Adesioye Temiloluwa (2016). Diet and Kidney Disease In: Diet and Diseases . Edited by Wu Wenbiao, Ph.D Food Science Nova Science Publishers Inc USA.

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- Oluwole O.B., Kosoko S.B., Owolabi S.O., Olatope S.O.A. and Elemo G.N. (2013): Influence of fermentation time on the proximate and pasting properties of sweet potato (*Ipomea batatas L*) flour. 9th Triennial Conference, African Potato Association. Kenya from (23 June – 4 July). Pp 158.

- Oluwole O.B., Oyegbami F., Kosoko S.B., Owolabi S.O., Bankole A. and Elemo G.N. (2012): Organoleptic characteristics of biscuits from blends of maize, sorghum and soybeans. In: - Proceedings of the 36th Annual Conference (15-19 October) of Nigerian Institute of Food Science and Technology. Pp 65 - 67.

- Adeboyejo F.O., Oladunmoye O.O., Oluwole O.B., Owolabi S.O., Oyegbami F.O., Aderele A.A. and Ozumba A.U. (2012): Alternative ingredient for local ready-to-use therapeutic foods (RUTF) in Nigeria. . In: - Proceedings of the 36th Annual Conference (15 - 19 October) of Nigerian Institute of Food Science and Technology. Pp 478-480.

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- Oluwole O.B., Kosoko S.B., Owolabi S.O., Odije E.E., Ozumba A.U. and Bankole, A. and Adeyoju A. (2012): Physico-chemical properties of developed soy-malt beverages. In: - Proceedings of the 35th Annual Conference (10- 14 October) of Nigerian Institute of Food Science and Technology. Pp 165- 166.

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- Oluwole O.B., Kosoko S.B., Owolabi S.O., Salami M.J., Iguodala E.I., Oke O.V., Joaquim A.A., Erukainure O.I., Ozumba A.U., Kayode F., Oresegun S., Bankole A.K., Elemo G.N and Olatunji O. (2010): Development and production of frozen pre-fried sweet potato chips as a suitable raw material for fast food centres. In: - Proceedings of the 6th Annual Research Conference and Fair (20-21 October) of University of Lagos, Nigeria. Pp 137.

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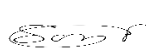

05/11/2024