EVALUATION OF QUALITY PROPERTIES OF PROTEIN-RICH SNACK BAR DEVELOPED FROM PRE-GELATINIZED TARO (*Colocasia esculenta* L.) FLOUR ENRICHED WITH SOYBEANS (*Glycine max* L.)

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not, wholly or in part, been presented for the award of a degree at Egerton University or any other institution.

Signature……………………………. Date…………04.07.2023……

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Recommendation

This thesis has been submitted with our approval as the official university supervisors.

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DEDICATION

This thesis is dedicated to my family, relatives, and friends for their unwavering support, love and encouragement throughout this journey. My parents, the late William Oyim Kachi and the late Jasinter Anyango Orwa, who passed away without seeing my achievements.

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ABSTRACT

Food producers make sure to offer quick-to-prepare, nutrient-dense food options that are suited to consumers' tastes and fast-paced lifestyles. Developing such foods is imperative given the need to address malnutrition, more so Protein Energy Malnutrition (PEM). As a result, manufacturers are now focused on investigating innovative strategies like food-to-food fortification, which involves enhancing traditional staple foods with locally accessible, nutrient-dense, and underutilised crops like taro and soybean flour. This study thus aimed at innovatively developing protein-rich snack bars from pre-gelatinized taro flour enriched with soybeans. Producing pre-gelatinized taro flour under varying conditions and assessing its physico-chemical properties was the first step. Second step was to enrich pre-gelatinized taro flour with soybeans (raw, malted, roasted, and malted-roasted) to make flour blends for snack bars. Subsequently, followed by evaluating the microbial safety, nutritional components, sensory attributes, and shelf life through proximate content analysis, *in-vitro* protein digestibility, descriptive and consumer sensory tests, and accelerated shelf testing using the Arrhenius model. The data obtained was analysed using Statistical Analysis System software and significance tested by performing an analysis of variance (ANOVA) at 5% significance level. .Pre-gelatinization by boiling significantly reduced the oxalate content (56.7%), while roasting resulted in the least reduction (36.2%). Boiling also resulted in flour with the highest bulk density (BD) (0.86g/cm3) and the lowest water solubility index (WSI) (9.39%). Steamed flour had the highest water absorption index (WAI) (3.81 g/g), water holding capacity (WHC) (4.59g/g), and swelling capacity (SC) (4.86 g/g). Enriching pre-gelatinized taro flour with soybeans significantly increased crude protein, lipid, gross energy value, and *in vitro* protein ddigestibility (IVPD). The crude protein content increased by a proportional range of 55.75-337.76%, crude fat content increased by 189.09% to 949.09%, and the gross energy value ranged from 2.46-13.53%. Total phenolic in the snack bars increased significantly as soybean flour inclusion level increased. The enrichment also significantly affected the sensory attributes of the developed snack bars. Compositing with roasted soy flour resulted in a snack bar with the highest colour intensity and highly perceivable aroma. Compositing with malted and malted-roasted soy flour resulted in less brittle snack bars. The Arrhenius model predicted shelf life showed that snack bars had a shelf life of between 29 and 72 days. The findings show that taro and soybeans have the potential to be used in protein-rich bars to combat malnutrition, like PEM. Utilisation of these ingredients has the potential to improve food security and nutrition in disadvantaged Kenyan communities.

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LIST OF ABBREVIATIONS AND ACRONYMS

AACC	Association of American Cereal Chemists
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ASLT	Accelerated Shelf Life Testing
CBS	Corn Blend Soy
CRD	Completely Randomized Design
DM	Dry matter
FAO	Food and Agriculture Organization of the United Nations
KALRO	Kenya Agricultural and Livestock Research Organization
KNBS	Kenya National Bureau of Statistics
Ksh	Kenya Shillings
PCA	Principle Component Analysis
PEM	Protein Energy Malnutrition
SDGs	Sustainable development Goals
SSA	Sub Saharan Africa
TBA	Thio Barbituric Acid
TCC	Total Coliforms Count
TVC	Total Viable Count
WHO	World Health organization

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Under nutrition poses significant health risks to children and adults, and has a high socio-economic impact. Approximately 7 million children globally, who are below the age of five years die yearly from treatable and preventable illnesses, with developing countries bearing the brunt of these deaths (Syeunda *et al.*, 2019; UNICEF, 2013). Malnutrition contributes to more than one-third of these mortalities. Currently, 22% of children under five years are still chronically malnourished globally, with 36% living in sub-Saharan Africa (SSA) (Hawkes & Fanzo, 2017). Protein-Energy Malnutrition (PEM) is one of the most common forms of malnutrition in low income-countries such as sub-Saharan Africa (SSA) (Oluchina, 2017). PEM is associated with a 50-60% mortality of children under five years and many morbidities (Nabeta *et al.*, 2015). By the year 2014, a Kenyan report showed that approximately 26%, 4%, and 11% of children below five years in age (preschool-aged) showed wasting, stunting, and underweight, respectively (KNBS & NACC, 2017; Masibo *et al.*, 2020).

The aetiology of PEM is mainly attributed to over-reliance on starch-based staples such as cereals and tubers, which are low in essential nutrients such as minerals and protein. It has been proposed that viable and sustainable ways of meeting the dietary demand for protein and energy are through the integration of foods rich in these important components of interest (El Bilali *et al.*, 2019). The ideology behind these ingredients' utilization is premised on their presumed availability and affordability as sources of protein, energy, minerals, phytochemicals and dietary fibre (Wanjala *et al.*, 2020). In addition, the World Health Organization of the United Nations (WHO/UN) recommends the development of novel products such as to provide consumers with nutritious and healthy options (WHO, 2004). In this sense, food products such as snack bars, which are gaining popularity as part of children and adult diets, are highly valued for their convenience and versatility (Constantin & Istrati, 2018).

Snack bars (SB) are ready-to-eat products processed by mixing various dry ingredients and combined using a binder (Rejeki *et al.*, 2019). They can supply a substantial amount of essential nutrients needed and abate hunger. Snack bars can also be taken either as a supplementary or complementary food (Herawati *et al.*, 2019). Exploitation of plant-based ingredients to develop protein-energy dense snack bars has become popular in recent years. Despite the fact that it could offer an alternative to alleviating malnutrition and assuring food and nutritional security, the use of taro-soybean flour composite in snack bars has not been widely researched.

In subtropical and tropical regions, taro (*Colocasia esculenta* Linn.) an herbaceous tuber crop, is regarded as a staple food (Rashmi *et al.*, 2018). According to FAO/UN report in 2018, the world taro production of is approximated at 10.3 million tonnes, of which Africa produces about 9.5 million tonnes (or 92.2 %). Rwanda and Burundi are the leading producers in the East African (EA) region at 2.1% and 1.1 %, respectively (FAOSTAT, 2018). Cultivation of taro in Kenya is by small-scale farmers in Nyanza, Western, Central and Rift Valley regions (Akwee *et al.*, 2015). Regrettably, less attention has been given to this underutilized crop in Kenya and hence, no statistical data has been documented for taro production in Kenya since 2017 by FAO. Taro corms have potential to provide an inexpensive nutritional energy source as they contain between 70-80% (DM basis) starch. The starch is 98.8% digestible making it ideal for people and children with digestive difficulties (Azene & Molla, 2017). On a dry matter basis (DM), like most tubers, the protein content in taro corms is low, ranging from 1% to 2% (Rashmi *et al.*, 2018); thus, there is a need to enrich it with protein-dense foods such as soybean. In Kenya, taro is mostly consumed in boiled, roasted, and fried forms. According to a review done by Kaur *et al.* (2013), the starch extracted from taro corms can be used in various foods, such as thickeners, noodle and infant food formulations.

Soybean (*Glycine max* L.) is a legume species that provides a relatively inexpensive source of good quality protein (43.2% DM) (Ronoh *et al.*, 2017). Soybean is superior to other plant proteins due to the fact that it contains the highest proportion of indispensable amino acids; although soybean is lacking in amino acids which contain sulphur like methionine (Farzana *et al.*, 2017). Additionally, soybean also contains unsaturated fatty acids such as α-linolenic (7%), a biologically significant ω-3 fatty acid. Owing to these beneficial qualities, soybean is an ideal ingredient for supplemental and complementary foods (Farzana & Mohajan, 2015). Soybean flour is used to formulate infant foods, make candies, tofu and blend with wheat to produce baked products such as biscuits and bread. However, despite these advantages, taro and soybean utilization remains limited. Taro contains acridity factors and anti-nutritional components such as oxalic acid, while soybean has a high concentration of anti-nutrients including trypsin inhibitors. Processing techniques such as pre-gelatinization, malting and roasting to reduce these factors (Adeyemo & Onilude, 2013) could provide an avenue for enhancing the use of taro and soybean, respectively.

Pre-gelatinization is a thermal processing technique that physically modifies the starch structure (Liu *et al.*, 2017). It entails applying sufficient heat to induce gelatinization of the starch after which it is dried and ground (Akubor & Igba, 2019). Pre-gelatinization results in flour with enhanced physicochemical and functional properties compared to the native flour; for instance, pre-gelatinized flour disperses freely in cold water and forms relatively stable suspensions (Ritruengdech *et al.*, 2011). There are many research studies on the production of modified starch from cassava, wheat, potato rice, and corn (Lestari *et al.*, 2019; Liu *et al.*, 2017; Melese *et al.*, 2015) and production of pre-gelatinized taro flour could as well add to these sources. Malting involves controlled germination during which amylase, protease and hydrolytic enzymes are synthesized. The activities of these enzymes result in the solubilization of protein and starch (Baranwal, 2018). Roasting is a thermal process used to improve flavour, colour and shelf life. The heat applied also inactivates enzymes and anti-nutrients such as trypsin inhibitors (Navicha *et al.*, 2018). The nutritional value as well as shelf-life stability of the snack bar are both affected by these various processing methods.

Shelf-life refers to the time/duration a food product is considered suitable to consume or use when kept in the proper conditions (Haouet *et al.*, 2018). Also, following the current EU legislation, shelf life is known as the "date of minimal durability," and this applies to foods that are not highly perishable and do not pose an immediate threat to public health (Commission, 2005). Accelerated shelf life (ASLT) and real-time stability tests (RTST) are typically utilized to predict shelf life. The products are stored in accordance with the prescribed environments and tracked until the specifications declines in RTST whereas for accelerated shelf life testing (ASLT) the products are stored at heightened stress condition to hasten the rate of product deterioration whilst maintaining the pathways and order of changes that occur during normal storage (Haouet *et al.*, 2018).

The present research focused on developing protein-rich snack bars by compositing pre-gelatinized taro flour with soybeans flour. This study evaluated total oxalate content and techno-functional properties of the pre-gelatinized taro flour, determined the microbial safety, nutritional composition, sensory and shelf life quality of the developed snack bar. To eliminate the anti-nutritional factors in taro and improve taro-starch digestibility pre-gelatinization processing technique was employed. Malting and roasting of soybeans were also deployed to enhance the overall protein digestibility and flavour in the formulated snack bar.

1.2 Statement of the Problem

Protein-Energy Malnutrition is still a serious national development and public-health concern in Kenya. The situation has also been worsened by the COVID-19 pandemic. This is primarily due to over-reliance on starch-based staples, which are deficient in essential nutrients like protein. Also, because of the high living standards, low-income households struggle to access affordable nutritious food to satisfy their nutritional requirements. Different strategies have been proposed to solve this problem, such as food-to-food fortification through compositing with locally available ingredients. The utilization of culturally acceptable ingredients such as taro and soybean composites seems to be a feasible approach in addressing PEM. Despite being a good source digestible starch, minerals, vitamins and bioactive components, taro remains under explored and underutilized in Kenya owing to its high perishability, anti-nutrients present and inadequate production. Processing techniques like pre-gelatinization have been used in the pharmaceutical industry to produce taro starch and eliminate anti-nutrients, however it effects on taro flour for food application has not been thoroughly explored. Also, like most cereal and root crops, the protein fraction in taro corms is low; thus, there is a need to enrich taro and taro products with foods such as soybean rich in proteins and other nutrients. Snack bar consumption has shown an increasing trend among children and adult diets to abate hunger between meals. Most snack bars available in the market are cereal-based, as such, these bars are rich in starch though deficient in additional essential nutrients. The protein bars are also are prohibitively expensive Therefore, developing nutritious snack bars from appropriate taro and soybean composite ratios could provide an inexpensive alternative to reducing PEM cases.

1.3 General Objective

The overall aim of this study is to contribute to food and nutrition security and reduction of protein-energy malnutrition through developing a protein-rich snack bar made from pre-gelatinized taro flour composited with soybeans.

1.3.1 Specific Objectives

i. To determine the effect of the pre-gelatinization conditions on the physico-chemical properties of taro flour.

ii. To determine the effect of enriching pre-gelatinized taro flour with soybean flour on the microbial and physico-chemical properties of the developed snack bar.

iii. To determine the effect of enriching pre-gelatinized taro flour with soybean flour on the sensory properties of the developed snack bar.

iv. To determine the effect of enriching pre-gelatinized taro flour with soybean flour on the shelf-life of the developed snack bar.

1.3.2 Hypotheses

i. The pre-gelatinization conditions has no significant effect on the physico-chemical properties of taro flour.
ii. Enrichment of pre-gelatinized taro flour with soybean flour has no significant effect on the microbial and physico-chemical properties of the developed snack bar.
iii. Enrichment of pre-gelatinized taro flour with soybean flour has no significant effect on the sensory properties of the developed snack bar.
iv. Enrichment of pre-gelatinized taro flour with soybean flour has no significant effect on the shelf life of the developed snack bar.

1.4 Justification

Kenya's population has grown three-fold in the past 35 years, hence straining the country's resources and leaving many people including children vulnerable to poverty and malnutrition (USAID, 2018). The situation has also been worsened by the COVID-19 pandemic (Ramos *et al.*, 2022). Despite the strides made by Kenya to reduce the prevalence of stunting nationally from 35% to 26% between the years 2008-2014, it has been too slow to achieve the 2030 global agenda Sustainable Development Goal 2 (KNBS & NACC, 2017). The country has also rolled out the Kenya Nutrition Action Plan (KNAP) 2018 – 2022 to mitigate nutrition related problems and sustainably end all stages and forms malnutrition (MOH, 2018). With the increasing demand for protein and energy it has been advocated that a combined approach of conventional food fortification and local food-to-food fortification using locally available, nutrient-dense foods is needed to ensure sustainable adequate nutrition (El Bilali *et al.*, 2019). Recent research findings indicate that food product manufacturers have integrated legumes into the conventional starch mainstays such as roots and tubers. The result of this combination has been a complementary-nutrient diversified product that could minimize the risk of PEM in the vulnerable groups.

Taro and soybean are underutilized locally accessible plant-based foods that can supply the nutrients of interest. Taro is rich in carbohydrates and other micronutrients but low in proteins (Rashmi *et al.*, 2018). As a functional food, it also contains bioactive substances such as Gallic acid, proanthocyanidins, and flavonols (Lestari *et al.*, 2019). In contrast, soybeans are a superior source of high-quality protein compared to other legumes (Farzana *et al.*, 2017). Indigenous processing techniques such as pre-gelatinization of taro, malting and roasting of soybeans can reduce the anti-nutritional factors present in taro, enhance protein and starch digestibility, improve mineral bioavailability and flavour. Pre-gelatinization produces flour with enhanced physicochemical and functional qualities and is also highly digestible (Wijanarka *et al.*, 2017). Snack bars are convenient ready-to-eat foods and can provide an excellent avenue for delivering the required nutrient as they are considered "fun-food" due to their sensory attributes (Lucas *et al.*, 2020). Typically, most snack bars have been predominantly made with wheat, corn, soy and rice flour (Momanyi *et al.*, 2020) as such, they cannot meet the nutritional needs of the consumer. Also, high-quality protein snack bars that are available in the market, are prohibitively expensive, making them out of reach for low-income households. In this context, food-to-food fortification i.e. taro and soybeans in developing the snack bars is necessitated as a cheap dietary intervention to alleviate PEM.

In addition to alleviating malnutrition and supporting children's growth and development, the developed snack bars in this study can be a helpful supplement to aid organisations and school feeding programmes. By including such snacks, vulnerable populations' nutritional health and general well-being may be improved (FAO, 2021). Additionally, these snack bars can be made to be shelf-stable, simple to distribute, and suited for a variety of dietary preferences. As a result, they are practical for use in emergency situations or school feeding programmes (WFP, 2021). It was therefore necessary to investigate the impact of the pre-gelatinization methods on the physico-chemical properties of taro flour and to ascertain impact of combining pre-gelatinized taro flour and soybean flour on the nutritional value, microbial safety, sensory and shelf-life qualities of the snack bars. The data gathered in this study will be essential for food processors and developers to develop novel and nutrient enhanced food products.

1.5 Definition of Terms

Agricultural marginalization is the systematic exclusion, disregard, or restricted access to resources, opportunities, and support mechanisms experienced by particular communities or regions within the agricultural sector, which results in their limited involvement, reduced productivity, and social and economic disadvantages.

Compositing refers to the method of blending different nutrient sources or ingredients to produce an enriched food product with increased nutritional value.

CHAPTER TWO

LITERATURE REVIEW

2.1 Protein Energy Malnutrition

Protein-energy malnutrition (PEM) happens when protein, energy or both, compared to physiological demands of the body, are inadequate in a diet (Keller *et al.*, 2020). The clinical manifestation of PEM in children under five years (pre-school age) includes underweight, marasmus, kwashiorkor and marasmic-kwashiorkor (Oluchina, 2017). The cause of PEM and malnutrition, in general, is multifaceted, with social, environmental and dietary factors contributing to the risk. In Kenya, a combination of improper feeding practices (due to ignorance) and nutritionally inferior diets (due to poverty) are the key factors in the aetiology of PEM (Akombi *et al.*, 2017). Additionally, over-reliance on starch-based staples such as cereals and tubers, which are low in essential nutrients like minerals and protein and contain anti-nutrients such as tannins also contribute PEM cases. Therefore, improving nutrition is a necessary prerequisite for reducing the high under-five PEM rates (Ubesie *et al.*, 2012). It has been proposed that viable and sustainable ways of meeting the dietary demand for protein and energy are through incorporating foods abundant in these nutrients of concern (El Bilali *et al.*, 2019) such as taro and soybeans.

2.2 Taro Crop

Taro (*Colocasia esculenta* L. Schott) is an annual herbaceous vegetatively propagated root crop native to subtropical and tropical areas (Rashmi *et al.*, 2018; Zhang *et al.*, 2017). Taro belongs to genus *Colocasia* and the superfamily *Araceae*, having its origin from South-east Asia. The crop is mainly cultivated for its edible leaves, corms, and cormels (Pereira *et al.*, 2015). The underground corms contain 70–80% starch making them an excellent source of carbohydrates. Taro is a low-cost and widely consumed staple crop that has constituted part of the human diet for nearly 9,000 years, placing it among the oldest food crops in the world. It is primarily consumed in boiled, fried, roasted, baked, and steamed forms (Azene & Molla, 2017). Reports indicate that taro was initially produced to address seasonal food shortfalls while other crops were in the field. This is due to the fact that it can produce a reasonable yield in environments in which other crops cannot produce due to different crop production limitations (Akwee *et al.*, 2015; Rashmi *et al.*, 2018). These reports imply that taro cultivation can play a vital role in promoting nutrition and food security and ensuring the sustainability of agriculture in developing countries, including sub-Saharan Africa (SSA).

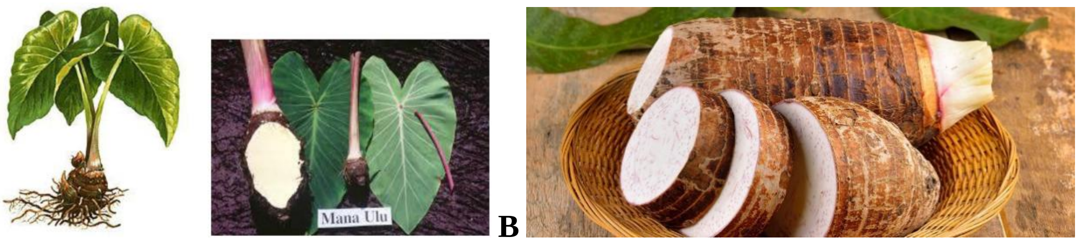
2.2.1 Taxonomy of Taro

Taro is classified in the genus *Colocasia* and family *Araceae* consisting of at least 100 genera and more than 1500 species. According to Banjaw (2017), there are two most widely cultivated species of taro: dasheen (*Colocasia esculenta var esculenta*) ,and the eddoe (*Colocasia esculenta var antiquorum*). The dasheen type has a large central corm with stalons and suckers, whereas eddoe has numerous smaller cormels and a tiny central corm. Genotypically taro has been categorized into wild and cultivated types. Quero-Garcia *et al.* (2010) purport that wild taro corms are unusable as food owing to their unusually high amounts of calcium oxalate crystals.

2.2.2 Morphological Characteristics of Taro

Taro is an annual monocotyledonous herb that is typically harvested between 5 and 12 months following maturity. Taro crop can reach up to a 2 m height with central corm resting beneath the soil's surface, roots growing downwards and leaf growing upwards, while cormels, daughter corms, and runners extend laterally (Kaushal *et al.*, 2015). The leaves of the taro crop are heart-shaped, and they can be green or purple. They possess fibrous roots, long petioles, and cylindrical or asymmetrical corms (Figure 2.1). The taro plant reproduces sexually by seeds and vegetatively through tubers, corms, and root suckers, aided by plant physiology and contemporary breeding techniques (Banjaw, 2017; Rashmi *et al.*, 2018).

A



B

Figure 2.1 Taro plant (A) and Taro corms (B). Source: Brown *et al.* (2016)

2.2.3 Global Production of Taro

According to UN/FAO report, the global taro production is approximately 10.3 million tonnes, of which Africa produces 9.5 million tonnes (about 92.2 %). In West Africa, Cameroon, Ghana, and Nigeria account for 11 %, 17 % and 58 %, respectively (FAOSTAT, 2018). Unfortunately, less focus has been placed on taro production, and as a result, FAO has not documented any statistical data about taro production in Kenya since 2017. Also, a report by Kenya Taro Market Insight (KTMI) has shown that between the years 2015 and 2018, taro exports decreased by -100%, with Kenya's share of the global total taro export at 0% in 2018 (Wamucii, 2021).

2.2.4 Nutritional Quality, Chemical Composition, and Significance of Taro Corms

The nutritive quality of a crop is evaluated when selecting it for use as a food source (Huang *et al.*, 2007). The proximal composition of taro varies according to the variety, growth condition, soil type, moisture, and agronomical practices, including fertilizer use, ripeness, and postharvest processing and storage measures. Considering they contain between 70-80% starch on a dry matter (DM) basis, taro root has a high nutritional potential to supply inexpensive dietary energy sources (Melese *et al.*, 2015). Because of tubers' high moisture content, the energy in tubers is roughly one-third that of a comparable amount of wheat or rice. The taro carbohydrate content is double that of potatoes and provides about 135 kcal per 100 g DM. These qualities are significantly higher than those of other tuber and root crops, including yam, cassava, and sweet potato (Melese *et al.*, 2015).

Taro corm is a good source of iron, phosphorus, calcium, niacin, riboflavin, and thiamine, all vital human dietary components. The protein fraction in the corms ranges between 1 and 2% DM (Table 2.1) (Rashmi *et al.*, 2018); thus, there is a need to enrich it with protein-dense foods such as soybeans. The corms have potassium and magnesium concentrations ranging from 2,251 to 4,143 mg/100 g and 118 to 219 mg/100 g DM, respectively (Kaushal *et al.*, 2015). Additionally taro corms have health benefits are they contain phytochemicals and phenolic compounds such as β-carotene, anthocyanin and cyanidin 3-glucoside (Rashmi *et al.*, 2018). According to Kaur *et al.* (2013), despite the fact that taro is not an industrial crop, the starch extracted from the corms can be applied in various food products. The small granule size also improves binding. The rheology of taro starches makes them particularly helpful in food uses requiring a considerable thickening agent. Their small particle size is especially advantageous for manufacturing bread and noodles (Melese *et al.*, 2015) and infant food formulations (Azene & Molla, 2017).

Table 2.1 Proximate composition of taro corms on wet weight basis (Charrondière *et al.*, 2013)

Component	Content
Moisture	63-85%
Carbohydrate (mostly starch)	13-29%
Protein	1.4-3.0%
Fat	0.16-0.36%
Crude Fibre	0.60-1.18%
Ash	0.60-1.3%
Vitamin C	7-9 mg/100 g
Thiamine	0.18 mg/100 g
Riboflavin	0.04 mg/100 g
Niacin	0.9 mg/100 g

2.2.5 Anti-nutritional and Other Factors limiting utilization of taro

Antinutritional factors present in taro corms include oxalates, proteinase inhibitors (trypsin and chymotrypsin), cyanogenic glycosides, lectins, alkaloids, steroids, tannins, and phytates (Rashmi *et al.*, 2018). One major impediment to taro use is the calcium oxalate crystals, as they impart an unpleasant, acrid taste which irritates the throat and mouth epithelium when raw or unprocessed foods from taro are consumed, thus indirectly affecting the digestibility. The oxalates can also penetrate soft skin and cause discomfort (Kaushal *et al.*, 2015). In large quantities, oxalate is toxic to humans and depreciates the nutrients in the food by binding to calcium. Du Thanh *et al.* (2017) studied taro corms in Vietnam and reported that the total oxalate level of the corms ranged between 127 and 831 mg/100g DM. According to a review done by Temesgen and Retta (2015), processing procedures such as sun drying, boiling and steeping in water can be employed to reduce the calcium oxalate content of the corms. Therefore, it is critical to evaluate the impact of the processing technique on this anti-nutrient in taro corms and determine whether they have a degrading effect on them to enhance mineral availability and ensure the safety of the food for consumption. Other factors limiting the use of taro include inadequate preservation methods since taro has high moisture content resulting in postharvest losses. The *Araceae* family in which taro belongs tend to bioaccumulate heavy metals when grown in a polluted area, a factor that is a food safety concern and limited research and information on the nutritional composition of taro.

2.3 Pre-gelatinization

Pre-gelatinized starch is basically cooked and dried starch. It can also be referred to as alpha starch. Pre-gelatinization entails applying sufficient heat to induce gelatinization of the starch, after which it is dried and ground (Akubor & Igba, 2019). It is the most extensively used approach in the food industry to physically modify starch. This hydrothermal processing technique is relatively easy, cheap, safe and high-yielding (Liu *et al.*, 2017). It can be achieved through microwaving, boiling, steaming, extrusion and roasting processes (To *et al.*, 2020). The modified starch can be applied in food as a thickening agent, in infant foods and salad dressings and in other non-thermally processed products.

The increased use of heat causes the hydrogen bonds, which link glucose within the starch molecule, to weaken. The weakening consequently destroys the granular structure and causes granular fragmentation and the eventual loss of birefringence property (Alcázar-Alay & Meireles, 2015). The consequent modified starch particle imbibe water readily expanding rapidly to achieve a larger granule size. This can affect the starch granule, resulting in increased solubility, absorption, gelatinization temperature, swelling power, and starch paste stability (Aktas & Gercekaslan, 2019). Polyphenol enzymes are also inactivated by pre-gelatinization. Numerous research investigations on the manufacturing of pre-gelatinized starch from wheat, rice, potato and corn have revealed that the outcomes of pre-gelatinization vary depending on the kind of the products (Lestari *et al.*, 2019; Liu *et al.*, 2017; Melese *et al.*, 2015). For example, according to a review done by Wijanarka *et al.* (2017), taro flour can be pre-gelatinized at 100°C for 20 or 40 min while cassava flour it can be done at 80, 90, or 100°C for 10 min and trifoliate yam flour at 100°C for 10 min.

2.3.1 Properties of Food Affected by Pre-gelatinization Process

Pre-gelatinization affect the physico-chemical properties of starch product. These effects can be quantified by laboratory measurements of the following properties;

i. Water Holding Capacity (WHC)

The quantity of water one gram of a sample can physically hold against gravity is its WHC. It can be defined as the amount of water one gram of test sample can absorb (Wijanarka *et al.*, 2017). When flour and water are combined, the modified starch granules and protein that may be present are hydrated by the water molecules. Studies have shown that because of the crystalline structure being disrupted as a result of the weakening of the inter-and intra-molecular hydrogen bonds resulting from starch gelatinization, the hydroxyl group is exposed and they form hydrogen bonds with water thereby binding the water molecules resulting in increased WHC (Liu *et al.*, 2017).

ii. Oil Absorption Capacity

Oil absorption capacity (OAC) is caused by capillary attraction entrapping oil physically. Because oils promote mouth feel and taste retention, the OAC of a product is a vital functional attribute in food formulations. From an industry perspective, OAC is of great importance since it reflects the emulsifying capacity. Foods such as whipped toppings, sausages, sponge cakes, and chiffon desserts use flour with a high OAC as a functional component (Kaur *et al.*, 2013). The OAC is also used to evaluate the capacity of dietary fibre to inhibit oil loss during food preparation and lower blood cholesterol levels by binding oil in the human digestive tract (Offiah *et al.*, 2019).

iii. Swelling Capacity and Solubility

Studies have demonstrated that the semi-crystalline structure of starch is disrupted when the particles are heated in excess water. When water is added to the flour, an association begins via hydrogen bonds between the water molecules and the exposed hydroxyl groups on amylopectin and amylose molecules. This interaction increases granule size and solubility and promotes swelling. (Awuchi *et al.*, 2019). Some foods, including as bakery products, use swelling capacity (index) as a measure of quality. It denotes the non-covalent association between starch granule molecules and a determinant of the ratio of α-amylose to amylopectin (Iwe *et al.*, 2016). The flours' swelling capacity (index) is impacted by the species variety, unit operations, processing method, and particle size.

iv. Bulk Density (BD)

The BD (g/cm3) represents the apparent density devoid of the impact of compression. BD is a characteristic of flours, powders, granules, fine particles, and other food-related substances (Chandra *et al.*, 2015). BD is not an inherent characteristic of the food matrix; the variation depends on how the food sample is prepared. The variation in BD of foods could also be attributable to differences in the flour's starch level, particle size, and moisture content (Mamat *et al.*, 2020). That is to say that, the higher the starch level, the greater the likelihood of an increase in BD. The flour's bulk density is utilized to establish its packing specifications. It specifies the porosity of a product and affects the type and design of the packaging material used (Iwe *et al.*, 2016). Higher BD flour necessitates packing materials that are denser. The BD of flour indicates its appropriateness for use in food preparations, i.e., flours with a low BD are beneficial in the development of complementary diets (Awuchi *et al.*, 2019). Various foodstuffs, such as bread, cookies, pastries, and cakes are composed primarily of starch.

2.4 Soybean

Soybean *(Glycine max* L.*)* is an essential legume crop with significant expansion potential in Africa and around the world. Soybean accounts for around 84.5% of the world's commerce in legumes. SSA accounts for around 1.3% of the world's total soybean acreage and 0.6% of global production (Murage *et al.*, 2019). According to a report by the UN/FAO, Kenya's annual soybean output is low; it is estimated to be at 2,007 metric tonnes (MT), (FAOSTAT, 2018). This has led to the importation of soybean to meet the increasing demand. Soybean is a multi-purpose crop and therefore, the dramatic rise in demand is attributed to its potential use as a feed, food and fuel crop (Chianu *et al.*, 2009). In regard to combating malnutrition in agriculture-dependent households, the soybean crop is also a viable alternative. It contains carbohydrates, fats, protein, dietary fibre, minerals and vitamins (Bruns, 2016; Sales *et al.*, 2016) (Table 2.2). In spite of these benefits, soybean adoption, production, and use have remained extremely low in Kenya and the rest of SSA (Abate *et al.*, 2012).

This legume species provides an inexpensive source of quality protein (43.2% DM)(43.2% DM) (Ronoh *et al.*, 2017). Based on the amino acid profile, soybeans tend to be superior to other pulses, as it includes the majority of the indispensable amino acids. Due to these advantageous qualities, soybean is an ideal ingredient for supplementary and complementary diets (Farzana & Mohajan, 2015). For instance, in developing nations, soy-based diets have been pushed as one of the sustainable methods for reducing PEM. In Western regions of Kenya, where the prevalence of PEM is high among pre-school-aged children, corn-soy blends (CSB) have been promoted to reduce the incidence (Ronoh *et al.*, 2017). There have been studies on the potential use of soybean in the formulation of infant foods, making candies, tofu and blended with wheat to make baked goods such as bread and cookies (Samtiya *et al.*, 2020). However, the opportunities to take advantage of soybeans into more healthful processed products such as snack bars are limited by anti-nutritional factors that negatively impact the nutritional quality and digestibility of the protein. The factors include phytates, tannins, trypsin inhibitors and some oligosaccharides (Adeyemo & Onilude, 2013). Gilani *et al.* (2012) reported that soybeans contain the highest concentration of trypsin inhibitors among common dietary and feed components. Soybean must therefore be subjected to some treatment before consumption to destroy or reduce this anti-nutritional content. This can be done through soaking, boiling, fermentation, malting and roasting processes.

Table 2.2: Basic Nutrient in Soybean Seed (Banaszkiewicz, 2011)

Nutrient	Soybean seed %
Dry matter	92.0
Crude Protein	42.8
Crude ash	4.86
Crude fat	18.38
Crude fibre	5.12

2.5 Malting and Roasting

Utilization of malted legumes has surged in the food system, particularly in weaning foods (Okoye *et al.*, 2018). Malting is a conventional food processing practice that has been utilized for centuries. It involves three steps of processing the pulse; steeping to enhance absorption of water, controlled germination (sprouting) and drying. This technique is believed to augment the cooking properties, nutritive value, and flavour of legume foods (Fox, 2018). During malting, anti-nutrients such as lectins, raffinose, tannins, trypsin inhibitors, and phytates are also broken down in legumes, hence enhancing the availability of vitamins, minerals, soluble sugars, and amino acids. (Harasym *et al.*, 2020). During the germination phase, protease synthesis, amylase production, and the synthesis of other endogenous hydrolytic enzymes are the most essential physiological actions linked to the process. The release of hydrolytic enzymes is increased, resulting in cell-wall disintegration, protein solubilization, and minimum starch hydrolysis, thereby releasing amino acids and soluble sugars (Baranwal, 2018). Research by Mezgebo *et al.* (2018) confirmed that malted soybeans had reduced tannins and trypsin inhibitors (TI) levels with improved protein quality and digestibility. The TI concentration reduced by 25.5% after seven days and the relative increase in essential amino acids was 8.9% after three days and 22.4% after six days of germination.

Roasting involves heating food by exposing it to dry heat in an oven or over an open flame or by covering the food with hot stones, embers, ashes or sand to enhance its colour, shelf life, and flavour (Navicha *et al.*, 2018). Besides, roasting also inactivates anti-nutritional factors, especially trypsin inhibitors a similar effect of malting and fermentation. It also results in an increase in the total amount of lipids and fatty acids. An investigation by Agume *et al.* (2017) revealed that the roasting process induced a greater increase in soy protein digestibility. Navicha *et al.* (2017) also reported that roasting of soybeans inactivates soymilk lipoxygenase activities. However, there is very little research on the impact of soybean malting and roasting on the nutritional qualities of a snack bar.

2.6 Current Trend in the Demand for Convenient Foods

Convenience encompasses people’s desire to save time and cognitive effort while engaging in the consumption process (Nakano & Washizu, 2020). The current trend in consumer lifestyle and behaviour shows that consumers prefer foods with purported health benefits that are also convenient for preparation, storage, and consumption. They prefer product which require less time to cook or are ready-to-eat (convenient) foods such as snack bars (Biemans, 2017). Convenient foods are food products that require minimum processing or preparation before consumption, such as rehydrating food in hot or cold water and moderate heating for ready-to-eat products (Brennan *et al.*, 2013). Snack industry has established itself as a major contributor to the global market for convenience foods. Kelly (2019) projected the global market for convenience meals to increase by 3.2% from $1.1 trillion in 2011 to $1.3 trillion in 2016. Majority of the world's population has included snacking into their eating habits. Consequently, well designed convenience products can boost overall food and nutrition security in communities where social and economic changes affect traditional food preparation patterns.

2.7 Snack Bars

Snack bars (SB) are gaining popularity as part of human diets owing to their convenience and versatility (Suhem *et al.*, 2017). Snack bars are products processed through mixing various dry ingredients and combined using a binder (Rejeki *et al.*, 2019). They are exceptional high nutritive value convenient foods which can supply a substantial amount of essential nutrients needed; protein, carbohydrates, fats, vitamins and abate hunger. Snack bars can be taken either as supplementary or complementary food (Herawati *et al.*, 2019). Initially, SB was introduced as an energy source for athletes; however, they have rapidly attracted the attention of other consumers. As revealed by International Markets Bureau market indicators, the bias for SB is substantially affected by the need to fulfil the desire for sweets, saving time, utilizing it as a source of energy, weight loss and nutrition (Constantin & Istrati, 2018). Snack bars are increasingly present in children and adult diet therefore, they can provide an excellent avenue for delivering the required nutrient for pre-school children to help curb PEM as they are considered “fun-food” because of their sensory attributes (Lucas *et al.*, 2020). In the production of snack bars, many food formulas have been utilized. For instance, Puangjinda *et al.* (2016) designed snack bars comprising popped rice for pre-school-aged children, Nurhusna *et al.* (2020) prepared a snack bar from sorghum and beans for pregnant women and Netshishivhe *et al.* (2019) developed maize-baobab based snack to enhance the utilization of baobab. However, the potential of taro-based SB in combination with soy-protein is underexplored and the information regarding the same is scanty, yet they have the ability to meet nutritional needs and reduce food insecurity in impoverished communities.

2.8 Protein Nutritional Quality

The assessment of protein quality attempts to evaluate a food's ability (as a protein source) to meet protein and essential amino acid requirements (Millward *et al.*, 2008). It indicates the extent to which a food satisfies the metabolic requirements for both nitrogen and amino acids to appropriately promote protein synthesis and, consequently, growth and development. Factors to consider when it comes to protein quality are protein digestibility and bioavailability (Tomé *et al.*, 2014). Protein quality is influenced by a number of variables, including amino acid profile, balance and quantity of dispensable and indispensable amino acids, and availability of limiting amino acids in a diet (Cherian, 2020). Different methods can be employed to ascertain protein quality and they include *in vivo* animal bioassays which consist of administering food to the desired animal and measuring the extent to which the terminal intestine assimilates nutrients. However, this method is costly and take a long period of time before conclusive results can be obtained (Bryan *et al.*, 2018). The other is *in vitro* laboratory analysis, which involves estimation of the amino acid score (Wolfe *et al.*, 2016) and protein digestibility corrected amino acid score (PDCAAS) (Boye *et al.*, 2012). It also evaluates enzymatic approaches that use either a single or multiple enzymes identical to the human gastrointestinal tract (GIT) enzymes with some modifications to stimulate physiological functions (Damodaran & Srinivasan, 2008).

2.9 Sensory Evaluation

When dealing with food, sensory analysis is important in understanding and controlling key aspects for consumer satisfaction and market success (Sirangelo, 2019). Several scientific approaches to precisely, reproducibly, and objectively quantify or assess human responses to stimuli have been established. Two methods can be used. First, the analytical or objective methods consisting of difference, ranking and quality tests, and the second are the hedonic or subjective methods that comprise preference, consumer and market tests (Drake, 2007). The most common sensory evaluation techniques are sensory descriptive analysis and consumer acceptability testing. A trained panel identifies and describes both qualitative and quantitative sensory aspects of a product during descriptive sensory analysis. Methods of sensory descriptive analysis include, for instance, flavour, texture, colour, taste profiles, and quantitative analysis (Yang & Lee, 2019). These methods can be used to uncover variations between product variants and situations, identify drivers of consumer hedonic responses, and investigate correlations between sensory and chemical properties. The data obtained can also be analysed statistically to obtain inference regarding the perceived sensory attribute of a product. It is therefore important to evaluate the sensory acceptability of snack bar developed from blend of taro and soy flour which have undergone the various treatments to obtain information for future industrial use.

2.10 Accelerated Shelf-life Testing

Determining shelf life implies investigating the deterioration of the product as a function of time. There are various methods documented in the literature for conducting shelf-life research, but the majority of them are based on the kinetic theory, which describes the rate of product degradation. The most of investigations have concluded that the majority of food components obey either zero-order or first-order kinetics (Mizrahi, 2000). Real-time stability (RTST) and accelerated shelf life tests (ASLT) are typically employed to predict shelf life. Real-time experimentation is the most accurate method for estimating a product's shelf life, however, this test can be time-consuming and costly because some foods are assumed to have a prolonged shelf life. In accelerated shelf life testing (ASLT) the products are stored at heightened stress condition to hasten the rate of product deterioration whilst maintaining the pathways and order of changes that occur during normal storage (Haouet *et al.*, 2018). These tests rely on the fact that the kinetic reaction is temperature-dependent. Consequently, the harsher conditions to which items are often subjected typically correspond to a somewhat higher storage temperature (Pedro & Ferreira, 2006). Most product degrading reactions are presumed to be based on Arrhenius reaction kinetics; the rate at which products degrade rapidly increases as the temperature increases. These deteriorative changes can then be determined through sensory evaluation and/or by instrumental or chemical analyses to ascertain product quality (Robertson, 2012). The data collected by ASLT can be interpreted and extrapolated to actual market conditions. Snack bars are susceptible to lipid oxidation, irrespective of lipid content. This can cause undesirable changes in flavour and odour, decrease sensory perception, safety and nutritional quality of the foods during storage, making the food to be un-palatable. Therefore, the preservation and extension of shelf life of SB is of utmost importance (Ryavanki & Hemalatha, 2018).

2.11 Research Gap

SSA continues to suffer the brunt of PEM in the world, causing major concerns to children's health and an impediment to long-term development. One of the key causes of PEM in Kenya is the use of poor-quality protein-deficient diets. Taro is a starch-rich, underutilised crop, although it is low in protein, as are other cereal mainstays. Globally snack bar consumption is increasing and is expected to continue for the foreseeable future. However, because most snack bars are starch-based and have low nutritional composition, they are unable to address the nutritional demands of the consumer, exacerbating cases of PEM. As a result, this research focused on resolving this issue by developing a snack bar from a composite blend of pre-gelatinized taro and soybeans. As a result, utilisation of these ingredients will increase, contributing to food and nutrition security in Kenya and beyond.

CHAPTER THREE

EFFECT OF PRE-GELATINIZATION CONDITIONS ON THE TOTAL OXALATE CONTENT AND TECHNO-FUNCTIONAL PROPERTIES OF TARO (*Colocasia esculenta*) FLOUR

Abstract

Like most roots and tubers, taro (*Colocasia esculenta*) corms have a short shelf-life due to the high moisture content, which aggravates their post-harvest losses. They also contain high amounts of calcium oxalates, limiting their use in food applications. To help add value and diversify the use of taro corms as well as curb food losses, various strategies have been proposed, such processing of the corms into flour. This study aimed at evaluating the total oxalate content and techno-functional properties of taro flour as affected by the pre-gelatinization conditions (i.e., method and time). Pre-gelatinized taro flour was prepared by subjecting peeled and cleaned taro corms to roasting (190°C), boiling (100°C), and steaming (100°C) for 10 min, 20 min and 30 min, respectively, for each method, followed by drying for 10h at 60°C and milling. Generally, all the properties of flour were significantly affected by the pre-gelatinization conditions ($P < 0.05$). The total oxalate content of the pre-gelatinized taro flour ranged from 33.26 to 76.90 mg/100 g. Pre-gelatinization by boiling significantly reduced the oxalate content (56.7%), while roasting resulted in the least reduction (36.2%). The flour colour i.e. L*, hue, and chroma ranged from 38.47-70.30˚, 42.64-69.43˚, and 7.78-10.58˚, respectively. Roasting resulted in flour with the largest L* (70.30˚) and hue angle (69.43˚). Boiling also resulted in flour with the highest bulk density (BD) (0.86g/cm3) and the lowest water solubility index (WSI) (9.39%). Steamed flour had the highest water absorption index (WAI) (3.81 g/g), water holding capacity (WHC) (4.59g/g), and swelling capacity (SC) (4.86 g/g). This study shows that pre-gelatinization (i.e. by boiling, steaming or roasting) significantly affects the total oxalate content and techno-functional properties of taro flour, which in turn influences its use in other food applications thus increasing the utilization and production of taro simultaneously.

3.1 Introduction

Under the threat of food insecurity, root and tuber crops play a vital role in enhancing food security. Low and medium-income countries such as those in sub-Saharan Africa (SSA) highly rely on them as staple foods for their nutrition and cash income (Scott, 2021). Roots and tubers account for 20% of dietary calories consumed in SSA countries (Dreyer, 2017). Several varieties and species are produced and consumed, including cassava, potatoes, sweet potatoes, and taro. They come in second in importance after cereals as carbohydrate sources. This is also backed up by data on their annual global production i.e. approximately 836 million tonnes with the main producers being Asia at 43% followed by Africa at 33% (Chandrasekara & Josheph 2016).

Taro (*Colocasia esculenta* Linn.) is an herbaceous perennial root crop used as a staple food in tropical and subtropical countries (Rashmi *et al.*, 2018). In terms of weight produced, taro rates after sweet potato, cassava, and potatoes as the fourth most significant root crop in the world. Taro is also the second most important staple root crop in terms of consumption, following sweet potato (Legesse & Bekele, 2021). According to FAO/UN report in 2018, the world production of taro is about 10.3 million tonnes, with Africa producing 9.5 million tonnes representing 92.2 %. When compared to other bordering taro exporting countries like Uganda, Rwanda, and Burundi, Kenya's taro production is incredibly low. Low value-added and processing levels as well as low quality planting materials are probably responsible for the low productivity of the taro production (Akwee *et al.*, 2015).

The corms obtained from taro have great potential to provide an economical source of dietary energy in the form of carbohydrates as they contain 70-80% (DM basis) starch. The starch is 98.8 % digestible; this makes it ideal for people and children with digestive difficulties (Azene & Molla, 2017). The corms also contain a significant amount of dietary fibre, vitamins such as A, C, E, B_6, folate and minerals such as magnesium, iron, zinc, phosphorous, potassium, manganese, and copper as trace elements (Hossain, 2016). However, apart from the high perishability of taro corms due to their high moisture content, their consumption and utilization have also been limited by the presence of anti-nutritional and acridity factors such as high amount of calcium oxalate crystals, which cause sharp irritation and burning in the mouth and throat (Dilek & Bilgiçli, 2021). In order to combat post-harvest losses and improve the production, utilization and consumption of taro, production of pre-gelatinized taro flour which could be applied in several food products such as thickeners, bakery products and infant food formulations have been envisaged.

Pre-gelatinization is a thermal processing technique that physically modifies the starch structure (Liu *et al.*, 2017). It involves applying heat sufficient to bring about starch gelatinization, followed by drying and grinding (Akubor & Igba, 2019). Pre-gelatinization significantly affects the physicochemical and functional properties of flour by disrupting the starch granular structure (Hasna *et al.*, 2020); as such, pre-gelatinized flour can absorb water and increase viscosity immediately even with cold water (Wadchararat *et al.*, 2006). The pre-gelatinized flour also has increased swelling power, solubility, water-holding capacity, and gelatinization temperature and starch paste stability. With the enhanced properties, the resulting flour is of good quality and can be used to develop novel food products (Wijanarka *et al.*, 2017). In this study, the aim was to investigate the effect of pre-gelatinization conditions on the total oxalate and techno-functional properties of taro flour.

3.2 Materials and Methods

3.2.1 Materials

Freshly harvested dasheen-type of taro corms (*Colocasia esculenta* var *esculenta*) were obtained from Embu County (Figure 3.1.), Kenya and processed at the Food Pilot Plant at the Department of Dairy and Food Science and Technology, Egerton University**.**

Figure 3.1: Taro corms (Colocasia esculenta var esculenta)

3.2.2. Preparation of Pre-gelatinized Taro Flour

Taro corm were cleaned, peeled, steeped in portable water and sliced to about 5 mm thickness using a kitchen slicer on a disinfected working top. Pre-gelatinized taro flour was prepared using the method described by Sun *et al.* (2018) with modifications as illustrated in Figure. 3.2; roasting (at 130°C,for 10 min, 20 min,and 30 min), boiling (95°C, for10 min, 20 min,and 30 min), and steaming (at 100°C, for 10 min, 20 min, and 30 min) methods, dried at 60°C for 10 h in a draft oven and milled. The flours were screened through an 80μ mesh sieve, and then stored in airlock plastic containers before using. Raw taro flour was used as a control.

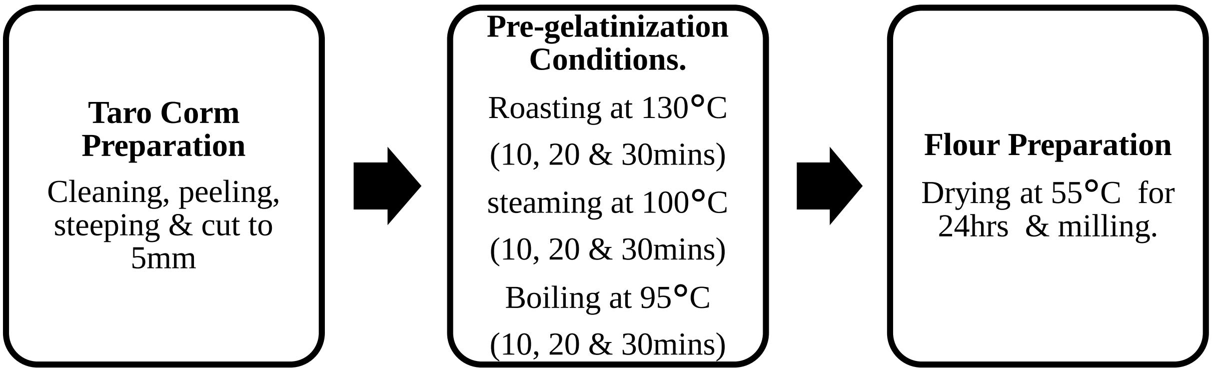


Figure 3.2: Flow-chart for Preparation of Pre-gelatinized Taro Flour

3.2.3 Determination of Total Oxalate Content

Analysis of the total oxalate content was done by HPLC method (Libert, 1981) with modifications suggested by Yu *et al.* (2002). Briefly, 0.5 g fresh weight of sample was homogenized in 4 ml of 0.5N HCl. The homogenate was heated at 80°C for 10 min with intermittent shaking (hot extraction). To the homogenate, distilled water was added up to a volume of 25 ml, then 3 ml of the solution was withdrawn and centrifuged at 12000 ×*g* for 10 min. Supernatant (1 ml) was passed through a microfilter (0.45µ) before HPLC analysis. Standards were prepared at varying concentrations for quantification (Figure 3.3). HPLC analysis was done using Shimadzu UV-VIS detector, Hypsil C_{18} column (5µ M, 4.6 mm *250 mm) HPLC grade water (550) was used as the static phase and the mobile phase was a solution 0.02M H_2SO_4. The flow rate was 0.6 $mlmin^{-1}$, the pressure of 62 kgf and the detection wavelength of 221 nm.

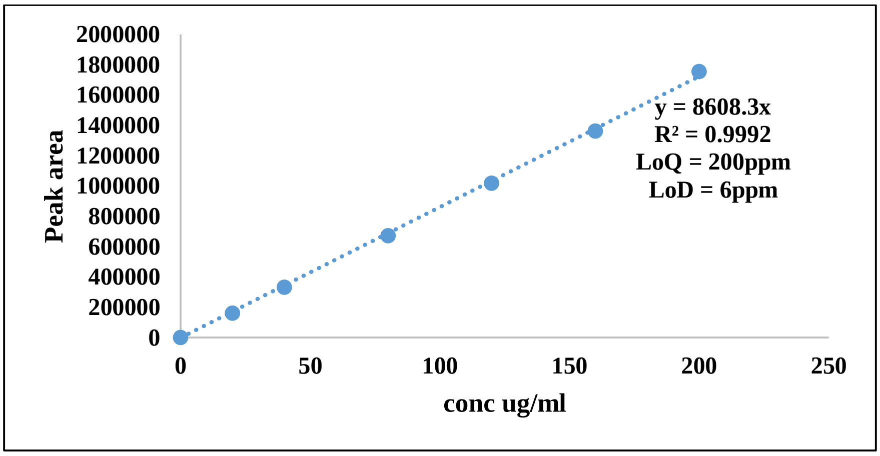


Figure 3.3: Standard Curve used for Determining Total Oxalate Content in Pre-gelatinized Taro Flour

3.2.4 Analysis of Techno-Functional Properties of Pre-gelatinized Taro Flour.

Colour Determination of flour samples was carried out using a Hunter colorimeter Model D 25 optical Sensor (Hunter Associates Laboratory Inc., Reston, VA., U.S.A.) based on L*(*lightness/darkness, 100 = white, 0 = black*), a* (redness/greenness, +, red; −, green) and b* (yellowness/blueness, +, yellow; −, blue) values as described (Olawoye & Gbadamosi, 2020)Hue angle (arctan [b^*/a^*] and Chrome (saturation index) ($[a^2 + b^2]^{1/2}$) was calculated as described by (McLellan, Lind & Kime,1995).

Bulk density (BD) was determined as described by Nicole *et al.* (2010).Taro flour (50 g) was measured in a graduated measuring cylinder (100 ml), and the volume was recorded. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level and the final volume recorded. The BD was calculated as the weight of sample per unit volume of sample (g/cm^3).

Water holding capacity (WHC) was determined according to the method described by Lapčíková *et al.* (2021) with slight modification. Distilled water (10 ml) was mixed with 1 g of sample in a pre-weighed centrifuge tube, vortexed, and left to stand at room temperature for 24 h. After which, centrifugation at 688 ×*g* for 15 min was done, then the supernatant was decanted and the residue was weighed, dried at 80ºC and reweighed. The WHC was expressed as grams of water per gram of dry flour sample, as shown in the equation (1) below.

$$WHC\ \left(\frac{g}{g}\right) = \frac{Weight\ of\ wet\ residue - Weight\ of\ dry\ residue}{Weight\ of\ dry\ residue} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Equation\ 1$$

Oil holding capacity (OHC) was determined as per the method described by Ratnawati, L. *et al.* (2019) with a slight modification. Samples (1g) were mixed with 10mlof corn oil in pre-weighed centrifuge tubes. The contents were vortexed for 1 min and left to stand at room temperature (25ºC) for 24 h. After which, the tubes were centrifuged for 15 min at 688 ×*g*. The separated oil was then removed with a pipette, and the tubes were inverted for 24hrs to drain the oil before reweighing. The OHC was expressed as grams of oil bound per gram of the sample on a dry basis.

Water absorption index (WAI) and Water solubility index (WSI) were determined as described by Yousf *et al.* (2017). Ground sample (1g) was, put into pre-weighed centrifuge tubes, and 10 ml of distilled water was then added. The tubes were vortexed and left to stand at room temperature (25ºC) for 24h. The tubes were then shaken and centrifuged at 688 ×g for 15 min. The supernatant portion was decanted into pre-weighed Petri-dish and dried at 105ºC for 12 h. The weight of the remaining gel in the tube was taken as the WAI (equation 2). WSI was calculated as shown in equation 3.

$$WAI(g/g) = \frac{Weight\ of\ wet\ residue - Weight\ of\ dried\ residue}{Weight\ of\ the\ sample} \text{………………………….. } \textit{Equation 2}$$

$$WSI(g/g) = \frac{Weight\ of\ dissoved\ solids\ in\ the\ supernatant}{Weight\ of\ dry\ sample \times 100} \text{ ……………………………………} \textit{Equation 3}$$

Swelling capacity **(SC)** was determined according to the method described by Vijay (2021)with a slight modification. Samples (1g) were weighed and placed in a graduated cylinder and the initial volume recorded. Distilled water (10 ml) at room temperature (25ºC) was added to the flour samples and mixed. It was tapped gently to eliminate air and let to stand for 24h, and the final volume was noted. SC was calculated as shown in equation 4 below.

$$SC = \frac{final\ volume\ wet\ residue}{initial\ volume\ dry\ sample} \text{…………………………………………………………} \textit{Equation 4}$$

3.2.5 Statistical Analysis

Data obtained was analysed using the PROC GLM procedure of the Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.1.The statistical evaluation employed a completely randomized design (CRD) in a 3×3 factorial arrangement. Test of significance was done by performing an analysis of variance (ANOVA) at 5% significance level. The means separation was done using Tukey’s Honestly significant difference (HSD) method. The results are expressed as mean ± standard deviation from three replication measurements.

3.3 Results and Discussion.

3.3.1 Effect of Pre-gelatinization Method on the Total Oxalate Content of Taro Flour.

The results for total oxalates is shown in Table 3.1. Raw taro had a total oxalate content of 76.90 mg. Pre-gelatinization by boiling for 10 min, 20 min, and 30 min reduced the oxalate content by 23.1%, 51.1% and 56.7%, respectively. Steaming for 10 min, 20min and 30 min reduced the oxalate content by 30.3%, 36.0%, and 42.08%, respectively. Roasting for 10 min, 20 min and 30 min reduced the oxalate content by 30.3%, 34.5% and 36.2%, respectively. Generally, pre-gelatinization by boiling method resulted in a significant reduction of the oxalate content, while pre-gelatinization by roasting resulted in the least reduction. The mean values trend also shows that all the pre-gelatinization methods decreased oxalate concentration on a dry matter basis and even further with prolonged time.

Dietary oxalates that occur due to the presence of calcium oxalate are detrimental to health as they are associated with aggravation of kidney stones and malabsorption of calcium when foods containing high amounts of oxalate are consumed (Chai & Liebman, 2005). For this reason, they need to be eliminated or reduced to acceptable levels since the oxalate restriction, which is defined as the dietary oxalate limit, is no more than 40-50 mg (Wanyo *et al.*, 2018). Oxalates can be reduced through processing methods such as soaking, fermentation and heating.

Heat thermally decomposes oxalates and can be done by either boiling, steaming, or baking/roasting. Also, in the presence of heat, the ascorbic acid (vitamin C) present in taro corms can be oxidized to form diketogulonic acid, which is unstable and breaks down to oxalate (Akter *et al.*, 2020). Boiling and steaming (wet heating) reduced the oxalate content of taro flour significantly when compared to roasting (dry heating) as a result of leaching (i.e., dissolution) of the soluble oxalates into the boiling and steaming water. This is corroborated by studies done by Albihn and Savage (2001) and Juajun *et al.* (2012) on the effect of cooking on oxalate concentration in three cultivars of New Zealand-grown Oca tubers (*Oxalis tuberosa*) and selected Thai vegetables, respectively. Also, according to a report by Kumoro *et al.* (2014), the kinetics of oxalate reduction follows a unimolecular or first order reaction. Thus, it is influenced by temperature and time, so the mean values of oxalate concentration decreased significantly with time across the different methods.

Table 3.1: Effect of Pre-gelatinization on the Total Oxalate Content of Taro Flour

METHOD	TIME**(mins)**	OXALATES **(mg/100g)**
Raw (control)	0	76.90^{a}±0.79
Boiling	10	47.76^{cd}±3.26
	20	37.59^{de}±1.44
	30	33.26^{e}±1.64
Steaming	10	53.64^{b}±1.06
	20	49.21^{bc}±5.30
	30	44.54^{cd}±1.86

Roasting	10	53.62^{b}±4.31
	20	50.39^{bc}±0.98
	30	49.07^{bc}±0.99

Key: Values are mean±standard deviations**.** The superscript letters along the column are mean separation showing significant difference at P<0.05; means in the same column with the same superscript letter are not significantly different.

3.3.2 Effect of Pre-gelatinization Method on Colour.

Table 3.2 represents the colour characteristics of pre-gelatinized taro flour. The results showed that the lightness (L^*) index of taro flour ranged from 38.47 to 70.30 which was significant at ($p<0.05$). Pre-gelatinization by roasting resulted in flour with a light L^* value of 70.30±0.95, whereas the control had an L^* value of 38.47±0.35. Hue (Hº) is the colour that the human eye can perceive, and it's critical for perception and acceptability of a product. Hue ranged from 42.64ºto 69.43º with pre-gelatinization by roasting having the largest hue angle. The chroma (Cº), which indicates the degree of colour saturation/intensity, ranged from 7.78 to 10.58, with control having the least value. The L^* value typically ranges from 0-100 with 0-being dark and 100-being the lightest (Olamiti *et al.*, 2020). The low L^* value obtained for the raw taro flour (control) can be due to the high concentration of colour pigments present in the taro corms i.e., anthocyanin, while the high value obtained (whiteness) from the pre-gelatinized taro flour can be attributed to the degradation of the anthocyanin (colour pigment) resulting in discoloration and thus the flour tending towards white. Red, yellow, and green colours are categorized and represented by H values of 0°, 90°, and 180°, respectively. The large Hº value obtained from flour prepared by pre-gelatinization by roasting can be attributed to the release of colour pigments from the reaction of heat and carbohydrates present in the taro flour such as caramelization (Damodaran & Srinivasan, 2008). These results are in tandem with the observations made by Njintang and Mbofung (2003) in their study where they noted that as degree of cooking increased, so did browning of taro flour due to the reaction of free sugars as a result of starch hydrolysis.

Table 3.2: Colour Characteristics of Pre-gelatinized Taro Flour

METHOD	TIME**(mins)**	Lightness (**L^***)	Hue (**Hº**)	Chroma (**Cº**)
Raw (control)	0	38.47^{f}±0.35	58.53^{c}±1.89	7.78^{e}±0.18

Boiling	10	61.17^{d}±1.85	50.64^{de}±1.23	10.09^{b}±0.30
	20	58.93^{e}±1.14	46.79^{fg}±2.24	9.98^{bc}±0.12
	30	58.60^{e}±1.90	45.16^{fgh}±0.64	9.59^{c}±0.18
Steaming	10	63.50^{c}±0.56	48.09^{ef}±0.69	10.58^{a}±0.10
	20	62.43^{cd}±1.75	43.51^{gh}±4.12	10.35^{ab}±0.20
	30	61.10^{d}±0.87	42.64^{h}±082	7.97^{e}±0.17
Roasting	10	59.03^{e}±1.19	51.45^{d}±1.89	10.32^{ab}±0.44
	20	65.30^{b}±0.17	63.77^{b}±1.25	9.89^{bc}±0.56
	30	70.30^{a}±0.95	69.43^{a}±0.83	8.90^{d}±0.01

Key: Values are mean±standard deviations**.** The superscript letters along the column are mean separation showing significant difference at ($P<0.05$); means in the same column with the same superscript letter are not significantly different.

3.3.3. Effect of Pre-gelatinization Method on BD, WAI, WHC, WSI, SC and OHC

Table 3.3 shows the results obtained from the analysis of the effect of pre-gelatinization conditions on other techno-functional properties of taro flour. Compared to the native flour i.e., raw taro flour, there was a significant increase in the functional properties ((BD, WAI, WHC, and SC) of the flours. Pre-gelatinization for 10min, 20min and 30 mins respectively increased the BD values by 10.26%, 8.97%, and 8.97% for boiling, 6.41%, 6.41% and 2.56% for steaming and 3.85%, 2.56% and 2.56% for roasting. The WAI value increased respectively by 107.2%, 84.43% and 80.84% for boiling, 128.1%, 105.9% and 85.63% for steaming, 73.65%, 54.49% and 43.71% for roasting. The WHC increased by 130.1%, 105.8% and 105.8% for boiling, 165.3%, 136.9% and 116.8% for steaming and 112.7%, 108.1% and 82.08% for roasting respectively. The WSI increased by 132.4%, 147.5% and 152.7% for boiling, 196.3%, 224.5% and 352.7% for steaming and 225.4%, 300.3% and 376.2% for roasting respectively. An increment of 280.4%, 227.5% and 213.7% for boiling, 376.5%, 320.6% and 280.4% for steaming and 287.3%, 208.82% and 110.78% for pre-gelatinization by roasting was observed for the SC. The BD, WAI, WHC, and SC generally decreased while WSI increased with prolonged pre-gelatinization time among the different methods. There was no significant difference in the OHC among the flour pre-gelatinized using different methods and time at ($P<0.05$).

Also known as the packing density, bulk density (BD) measures the heaviness of the flour. It is a vital parameter in determining how the flour should be handled, i.e., suitability of application in particular food formulations, packing, storage, and transportation. It reflects the load the sample can carry if allowed to rest directly on one another. In the present study, BD ranged from 0.76 to 0.86 for the different treatments. The results showed a significant difference at ($P<0.05$) these values are close to those observed by Yulianto *et al.* (2019) for partially pre-gelatinized starch from cassava (0.80g/ml) and higher than those observed in pre-gelatinized sweet potato flour (0.5g/ml) by Marta and Tensiska (2017). High BD is desirable as it offers an excellent packaging advantage as large quantities may be packed within a constant volume. The high BD also suggests their suitability to function as a thickener in food products as it helps to reduce paste thickness which is an essential factor in convalescent and child feeding. At the same time, low BD is helpful in formulating infant and weaning foods (Ratnawati *et al.*, 2019). Higher bulk density is desirable for greater ease of dispensability of flours (Onyeneke, 2019).

The general increase in WAI, WHC, WSI and SC of the pre-gelatinized taro flours when compared to the raw taro flour can be attributed to the fact that during pre-gelatinization there is the destruction of starch granules, reduction in the degree of crystallinity, and degradation of starch molecules as confirmed in a study done by Majzoobi *et al.* (2011) to determine the effect of pre-gelatinization by twin drum drier on physicochemical properties of wheat starch. Upon heating, the starch granules are susceptible to loosening with a limited chance of re-association as their semi-crystalline structure is broken. This phenomenon causes the substantive change in the starch structure by disrupting starch molecules' hydrogen bonding and exposing the side chains (Lutfi *et al.*, 2017). When water is added to the flour, the water molecule is associated with hydrogen bonding to the hydroxyl groups exposed on the amylose and amylopectin molecules, hence increasing WHC. Also, according to Aboubakar (2008), Betene *et al.* (2020) and Kaur *et al.* (2013) the increased WHC can be attributed to the high carbohydrate content of taro flour as well as the non-starch components such as mucilage and fibre which contribute high to water absorption capacity of taro flour. The interaction of water molecules and the hydroxyl groups also causes expansion and increases the size of the starch granules hence, increasing SC as it depends on the hydrogen bonding (Lawal *et al.*, 2015; Lutfi *et al.*, 2017). Because of the change to the structure of the starch granules there is increased fragmentation of amylose and amylopectin and as such they are leached (Lai, 2001) and consequently increased WSI. The water is also able to penetrate into the starch matrix and thus increase WAI. Lutfi *et al.* (2017) and Han *et al.* (2010) also noted a similar trend in their studies on the morphological, physicochemical, and pasting properties of modified water chestnut (*Trapa bispinosa*) starch and the effects of particle size and gelatinization of Job's tears powder on the instant properties respectively. WAI may have also been enhanced by mucilage present in taro corm flour (Kaur *et al.*, 2013).

However, the general decreasing trend of WAI, WHC and SC across the different pre-gelatinization methods with time can be attributed to the fact that with prolonged pre-gelatinization time, the starch can become completely gelatinized i.e. process by which the starch granules absorb water, expand, and degrade, forming a thick gel as a result; this interferes with the hydrogen bonding (disrupts) causing them to break and resulting in complete starch fragmentation with loss of birefringence, and this consequently affects the WHC and WAI negatively (Akubor & Igba, 2019; Lawal *et al.*, 2015). The SC may have decreased due to the dentation of the starch granules (Lutfi *et al.*, 2017). This can be attributed to the destruction of starch granules, reduction of the degree of crystallinity, and degradation of starch molecules during pre-gelatinization. This can be attributed to the destruction of starch granules, reduction of the degree of crystallinity, and degradation of starch molecules during pre-gelatinization.

Table 3.3: Other Techno-functional Properties of Pre-gelatinized Taro Flour

Key: BD- bulk density; AP- apparent porosity; FC-foaming capacity; WAI-water absorption index; WHC-water holding capacity; SC-swelling capacity; OHC- oil holding capacity; Values are mean±standard deviations**.** Superscript letters along the column are mean separation showing significant difference at $P<0.05$; means in the same column with the same superscript letter are not significantly different.

3.3.4 Correlation Coefficients of Functional Properties of Pre-gelatinized Taro Flour

Correlation coefficients of functional properties of taro flour pre-gelatinized using different methods and time are shown in Table 3.4. Bulk density strongly significantly affected positively WAI (r=0.75), WHC (r=0.59), and SC (r=0.56). Water Absorption Index significantly affected positively WHC (r=0.95) and SC (r=0.95). Water holding capacity significantly affected positively the WSI (r=0.54) and SC (r=0.96).The water solubility index significantly affected positively the SC (r=0.55). WAI, WHC, WSI and SC have positively correlated due to the fact the upon hydration with water, the pre-gelatinized starch granules which have their structure rearranged, the water can penetrate the starch matrix, and the exposed hydroxyl end is associated with water molecule through hydrogen bonding this result

Pre-gelitinization Method	Time (mins)	BD g/cm3	WAI g/g	WHC	WSI %	SC g/g	OHC
Raw Taro (control)	0	$0.78^{e} \pm 0.01$	$1.67^{h} \pm 0.01$	$1.73^{g} \pm 0.06$	$4.04^{h} \pm 0.01$	$1.02^{g} \pm 0.05$	$0.50^{a} \pm 0.14$
Boiling	10	$0.86^{a} \pm 0.00$	$3.46^{b} \pm 0.01$	$3.98^{c} \pm 0.00$	$9.39^{g} \pm 0.01$	$3.88^{c} \pm 0.08$	$0.53^{a} \pm 0.05$
	20	$0.85^{a} \pm 0.00$	$3.08^{c} \pm 0.01$	$3.56^{e} \pm 0.03$	$10.00^{fg} \pm 0.06$	$3.34^{d} \pm 0.01$	$0.46^{a} \pm 0.03$
	30	$0.85^{ab} \pm 0.0$	$3.02^{d} \pm 0.01$	$3.57^{e} \pm 0.01$	$10.21^{f} \pm 0.2$	$3.20^{e} \pm 0.00$	$0.41^{a} \pm 0.00$
Steaming	10	$0.83^{bc} \pm 0.01$	$3.81^{a} \pm 0.01$	$4.59^{a} \pm 0.04$	$11.97^{e} \pm 0.42$	$4.86^{a} \pm 0.07$	$0.46^{a} \pm 0.00$
	20	$0.83^{c} \pm 0.00$	$3.44^{b} \pm 0.02$	$4.10^{b} \pm 0.01$	$13.11^{d} \pm 0.37$	$4.29^{b} \pm 0.01$	$0.52^{a} \pm 0.02$
	30	$0.80^{d} \pm 0.00$	$3.01^{d} \pm 0.02$	$3.75^{d} \pm 0.05$	$18.29^{b} \pm 0.19$	$3.88^{c} \pm 0.01$	$0.51^{a} \pm 0.02$
Roasting	10	$0.81^{d} \pm 0.01$	$2.90^{e} \pm 0.03$	$3.68^{de} \pm 0.08$	$13.15^{d} \pm 0.37$	$3.95^{c} \pm 0.02$	$0.47^{a} \pm 0.03$
	20	$0.80^{de} \pm 0.01$	$2.58^{f} \pm 0.03$	$3.60^{e} \pm 0.02$	$16.17^{c} \pm 0.15$	$3.15^{e} \pm 0.04$	$0.49^{a} \pm 0.04$
	30	$0.80^{de} \pm 0.00$	$2.40^{g} \pm 0.01$	$3.15^{f} \pm 0.02$	$19.24^{a} \pm 0.39$	$2.15^{f} \pm 0.01$	$0.50^{a} \pm 0.02$

in swelling and increase in size and may burst to release the amylase which solubilizes in the water (Kouakou *et al.*, 2013). WAI indicates the flour's ability to absorb water within its matrix and swell for desirable consistency in food systems. This improves consistency and yield, giving body to the developed food product (Arivuchudar, 2018). It represents the ability of a product to associate with water under conditions where water is limited (Suresh & Samsher, 2013). WSI indicates the level of starch degradation (Arivuchudar, 2018).

	BD	WAI	WHC	WSI	SC	OHC
BD	1	0.75^{***}	0.59^{***}	-0.17^{ns}	0.56^{**}	-0.23^{ns}
WAI		1	0.95^{***}	0.30^{ns}	0.95^{***}	-0.08^{ns}
WHC			1	0.54^{**}	0.96^{***}	-0.08^{ns}
WSI				1	0.55^{**}	0.03^{ns}

SC	1	-0.05^{ns}
OHC		1

Table 3.4: Correlation Coefficients of Functional Properties of Pre-gelatinized Taro Flour

Key: MC-moisture content; BD- bulk density; AP- apparent porosity; FC-foaming capacity; WAI-water absorption index; WHC-water holding capacity; SC-swelling capacity; OHC- oil holding capacity; ns-not significant at P<0.05; ***- significant at P<0.001; **- significant at P<0.01 and *- significant at P<0.05.

3.4 Conclusion

The different pre-gelatinization conditions significantly affect the total oxalate content and techno-functional properties of taro flour compared to the native flour. Boiling significantly reduces the total oxalate content; steaming results in flour with the highest water holding capacity, water absorption index, and swelling capacity; Roasting affects the colour characteristics of taro flour as it produces flour with the largest Lightness and Hue index. Owing to these properties, the suitability of pre-gelatinized taro flour can be determined for application in various food products such as thickening agent, formulation of complementary and bakery food products, and increase its utilization and production simultaneously.

CHAPTER FOUR

EFFECT OF ENRICHING PRE-GELATINIZED TARO (*Colocasia esculenta*) FLOUR WITH SOYBEAN FLOUR (*Glycine max* L.) ON THE PROXIMATE COMPOSITION, *INVITRO* PROTEIN DIGESTIBILITY AND TOTAL PHENOLIC CONTENT OF THE DEVELOPED SNACK BARS.

Abstract

The current research focused on enhancing the nutritional density and quality of taro flour by enriching it with soybeans and producing snack bars to help ameliorate protein-energy malnutrition (PEM) cases in both adults and children. By substituting raw, malted, roasted, and malted-roasted soybean flour in proportions of 10%, 20%, 30%, and 40%, sixteen variants of the snack bars were prepared. The proximate composition, IVPD, Pb and Cd concentration and total phenolic content were determined to establish the nutritional profile. Complementing taro with soy significantly increased protein, lipid, energy, and IVPD. The crude protein content ranged from 3.39-14.84%, crude fat content ranged from 1.1% to 11.54%, and the energy value ranged from 4.04-9.4%. Malting resulted in increased proteins and fats and reduced carbohydrate content. Raw taro flour contained Lead (Pb) and Cadmium (Cd) concentrations of 0.928±0.066 mg/kg and 0.720±0.052mg/kg, respectively, while pre-gelatinized taro snack bars contained Lead concentrations of 0.035±0.001mg/kg. Total phenolic in the snack bars increased significantly as soybean flour inclusion increased. In conclusion, combining taro and soybean flour into snack bars could be used to produce snack bars and consequently increasing the utilization of both taro and soybeans. These snack bars showed that all nutritional parameters increased significantly, especially protein and IVPD and can therefore be used to reduce PEM in Sub Sahara African households.

4.1 Introduction.

According to the World Health Organisation (WHO), protein-energy malnutrition (PEM) and other forms of malnutrition occur when a person's cellular nutrient and energy supply is insufficient to meet the body's demand for these nutrients and energies in order to sustain growth, development, and specific body functions (WHO, 2018). Infants, children, pregnant women, and the elderly are particularly vulnerable to PEM, which places a tremendous burden on the healthcare systems of developing countries. Inmates, the mentally ill, and those with HIV/AIDS are also at risk (Jee, 2021). According to the World Health Organisation, 60% of all deaths in children under the age of five in underdeveloped countries are attributable to malnutrition (Nabeta *et al.*, 2015).

The majority of the world's population exposed to PEM lives in sub-Saharan Africa. Malnutrition rates rose from 181 million in 2010 to 222 million in 2016, as reported by Onyango *et al.* (2019), and PEM was found to be prevalent in children younger than five years of age in numerous African countries, with an average frequency of 40% (Oluchina, 2017). A Kenyan report from 2014 indicated that approximately 26%, 11%, and 4% of preschool-aged children exhibited stunting, underweight and wasting, respectively (KNBS & NACC, 2017; Masibo *et al.*, 2020). Oluchina *et al.* (2013) and Jee (2021) have linked a series of illnesses to PEM, including marasmus, kwashiorkor, and marasmus-kwashiorkor intermediate phases, lower respiratory illnesses, diarrhoea, malaria, and anaemia. These co-morbidities may prolong hospital stays and child deaths (Gudu *et al.*, 2020).

The aetiology of PEM is majorly attributed to over-reliance on starch-based staples such as cereals and tubers, which are low in essential nutrients such as minerals and protein. Improving nutrition is, therefore, a viable, sustainable, and important prerequisite to reducing PEM. This can be done by integrating ingredients rich in these nutrients of interest (El Bilali *et al.*, 2019). As WHO (WHO, 2004) recommended, taro and soybean can be blended and formulated into innovative food products and snack bars that provide healthy and nutritious choices for consumers. Snack bars are exceptionally high nutritive value foods that can supply the essential nutrients needed, such as protein, carbohydrates, fats, and vitamins, and abate hunger. Consumers appreciate their versatility, sensory attributes, and convenience (Suhem *et al.*, 2017).

As a result of their high starch content i.e.70-80% on a DM basis, taro roots have a great nutritional potential to serve an economical supply of energy from food as they contain 70-80% starch on a DM basis (Melese *et al.*, 2015). Taro tubers are rich in nutritionally useful phytochemicals and vital vitamins and minerals (Kaushal *et al.*, 2015). Soybeans are a cheap source of high-quality protein (43.2% DM) (Ronoh *et al.*, 2017). The beans contain most indispensable amino acids, making it superior to other plant proteins. It also contains beneficial bioactive compounds such as phytoestrogen isoflavones (Pramitasari *et al.*, 2018). This study therefore sought to evaluate proximate composition, *invitro* protein digestibility and total phenolic content of taro and soybean composited flour-based snack bars. However, to eliminate the anti-nutritional factors i.e., oxalates in taro, a pre-gelatinization processing technique will be employed. Malting and roasting were also done to enhance protein quality and digestibility by reducing anti-nutritional and flatus-producing factors present in soybeans.

4.2 Materials and Methods

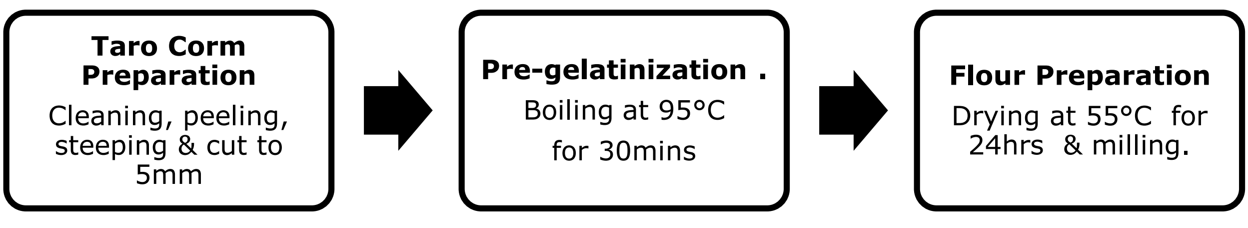
4.2.1 Materials

Experimental analyses were carried out at the departments of Dairy and Food Science and Technology, Chemistry and Animal Science at Egerton University. Freshly harvested dasheen-type of taro corms (*Colocasia esculenta var. esculenta*) were obtained from Embu County. Soybeans (*Glycine max* L.)- Nyala variety was obtained from KALRO-Njoro in Nakuru County, and the confectioner's glucose syrup processed from corn starch was sourced from the local supermarket in Nakuru town, Kenya. The snack bars were processed at the Food Pilot Plant at Egerton University's Department of Dairy and Food Science and Technology.

4.2 2 Preparation of Pre-gelatinized Taro Flour

Taro corms were cleaned, peeled, steeped in portable water, and sliced to about 5 mm thickness using a kitchen slicer on a disinfected working top. The procedure outlined by Sun *et al.* (2018) with modifications was used to prepare pre-gelatinized taro flour by boiling at 95°C for 30 min, followed by drying at 55°C for 24hrs and milling. The flour was then screened through an 80µ mesh sieve and stored in airlock plastic containers before use (Figure 4.2).

Figure 4.1: Flow-chart for Preparation of Pre-gelatinized Taro Flour



4.2.3 Preparation of Malted and Roasted Soybean Flour

Foreign material was effectively removed from whole grains of soybeans employing dry cleaning techniques. The procedure outlined by Tizazu *et al.* (2010) and Mezgebo *et al.* (2018) was followed in preparations of malted soy flour (2018). Soybeans were soaked after washing for 18 hours at room temperature in sufficient potable water, changing the soaking water every 6hr. After 18h of soaking, the water was drained followed by rinsing off the remaining soybean seeds in distilled water. Following soaking, the soybeans were spread out in growth boxes and left in a dark room (at 25°C) for 72 hours before being dried at 50°C for 24 hours in a hot air oven. Roasting a portion of malted and unmalted soybeans was done in the oven at 180°C for 20 minutes with occasional stirring (Ronoh *et al.*, 2017). All the soybeans were then milled into flour.

4.2.4 Composite Flour Formulation

Five blends each of pre-gelatinized taro, malted, roasted, malted-roasted, and raw soybean flour were produced by blending them in the levels of (taro: soybean flour) 100:0; 90:10; 80:20; 70:30 and 60:40 as shown Table 4.2.

Table 4.1: Composition Table Showing Ratios of Pre-gelatinized Taro to Soybean Flour

Ingredient	Taro: Soy Flour				
Ratio	**100:0 (Control)**	**90:10**	**80:20**	**70:30**	**60:40**
Pre-gelatinized Taro	100:0 (**PRGT)**				
Raw Soy Flour	100:0 (**PRGT)**	90:10 **(RST1)**	80:20 **(RST2)**	70:30 **(RST3)**	60:40 **(RST4)**
Malted Soy Flour	100:0 (**PRGT)**	90:10 **(MST1)**	80:20 **(MST2)**	70:30 **(MST3)**	60:40 **(MST4)**
Roasted Soy Flour	100:0 (**PRGT)**	90:10 **(RDST1)**	80:20 **(RDST2)**	70:30 **(RDST3)**	60:40 **(RDST4)**
Malted-Roasted Soy Flour	100:0 (**PRGT)**	90:10 **(MRST1)**	80:20 **(MRST2)**	70:30 **(MRST3)**	60:40 **(MRST4)**

Key: The abbreviation with numbers are the ratios of composition of pre-gelatinized taro with soybean flour of different treatments at different levels.

4.2.5 Snack Bar Preparation

The snack bars were prepared by modifying the procedure outlined by Momanyi *et al.* (2020). In a bowl, 100g of flour blend was mixed with molten glucose syrup in a ratio of 4: 3. Sugar syrup acted as a binder. The mix was then compacted in a rectangular (39.8×26×1.5cm) carbon steel non-stick baking tray lined with a baking sheet and rolled to take the shape of the pan, after which it was baked at 170 ºC for 20 mins**.** The bars were then cooled, cut into small rectangular (≈ 45mm*30mm) shapes and sizes, and packaged in zip lock polythene bags.

4.2.6 Proximate Composition Analysis

i. *Moisture Content*

The oven drying method (AACC (2010) Method 44-15A) was used. Two grams of samples was accurately weighed and transferred into aluminium dishes. The samples were dried in a dry air oven at 105ºC to constant weight and cooled in a desiccator for 10 min. The amount of moisture in percentage was calculated as follows:

$$\%Moisture\ content = \frac{weight\ of\ pan + wet\ sample(g) - weight\ of\ pan + dry\ sample(g)}{weight\ of\ sample\ (g)} \times 100$$

ii. *Ash Content*

Ash content was determined using AOAC (2000), Method 942.05; a muffle furnace (Model: MR170; S/N: 6800616; Heraeus GMBH, Hanau, Germany) was used. Two grams of the sample was accurately weighed and placed into silica crucibles. The analysis was done in triplicates. The samples was ashed in a muffle furnace at 550ºC for 3 h. The ash was cooled in a desiccator to room temperature (25ºC) and weighed. Ash content was calculated as a percentage of the dry sample.

$$\%Ash\ content = \frac{weight\ of\ crucible + ash(g) - weight\ of\ crucible(g)}{weight\ of\ sample\ (g)} \times 100$$

iii. *Crude Fibre*

The crude fibre was determined according to AOAC (2000), Method 962.09. Approximately 2 g of known dry matter content sample was weighed into a graduated beaker and 200 ml 2.04M sulphuric acid and bumping chips was added. The sample was boiled for 30 min and then filtered through a muslin cloth. It was then washed with boiling distilled water until no longer acidic, then boiled with 200 ml 1.73M potassium hydroxide solution for 30 min and filtered through a muslin cloth. After which, it was rewashed with 25ml boiling 1.25% H_2SO_4, 3.50 ml portions of distilled water and 25 ml ethanol. All this was carried out in a digester. The residue was removed and transferred to a pre-weighed porcelain dish (W1), dried in an air draft oven for 2 hours at 105˚C, cooled in a desiccator, and weighed (W2). The sample in the porcelain dish was then transferred to a muffle furnace, ignited at 550˚C to a constant weight, then cooled in the desiccator and reweighed (W3).

$$\%\ Crude\ fibre = \frac{(W2 - W1) - (W3 - W1)}{Weight\ of\ sample} \times 100$$

iv. *Crude protein*

Crude protein content (N × 6.25) was determined according to AOAC (2000), Method 984.13. About 2 g ground sample of known dry matter content was accurately weighed and mixed with 20 ml of concentrated sulphuric acid in a clean well-labelled digestion tube. Kjeldahl tablets (catalyst) were added to the mixture (selenium powder and concentrated sulphuric acid (2.8 g/800-ml), in the tube, and the sample was digested in a Gerhardt Kjeldahl therm digester (Model: KB40; Gerhardt GMBH and CO. Kg; Germany) for 1 h at 420˚C. Distilled water was added to the digest to make an 80 ml volume. Precisely 50 ml of sodium hydroxide solution was added to the mixture and followed by distillation of the ammonia into concentrated boric acid using a 2200 Kjeltec TM auto distillation unit (Foss Analytical, Höganäs, Sweden). Titration was done using hydrochloric acid (0.1M) after adding 2-3 methyl orange indicator solution droplets.

The percent nitrogen obtained was multiplied by 6.25 to convert to percent protein.

$$\%\text{N} = M\ \text{HCl} \times \frac{Corrected\ acid\ volume}{g\ of\ sample} \times \frac{14g\text{N}}{mol} \times 100$$

Where; *M* HCl= molarity of HCl, in mol/ 1000 ml

Corrected acid volume = (ml std. acid for sample) - (ml std. acid for blank)

14 = atomic weight of Nitrogen. Crude protein content will be obtained by multiplying the nitrogen content by 6.25.

v. *Crude Fat*

Crude fat was determined by the Soxhlet method (AOAC, 2000), Method 920.39. Approximately 2g ground sample of known dry matter content was weighed accurately into an extraction thimble and covered with cotton wool. The thimble was placed into the soxhlet extractor (Model: EME 6250/CF; Cole Parmer; England), and the fat was extracted into a tared flask for 6h using petroleum ether (B.P. 40-60 °C). The solvent was evaporated, the flask cooled in a desiccator, and weighed. The crude fat content was calculated and expressed as a percentage of the sample dry matter content.

$$\%\ Crude\ fat\ content = \frac{\text{Weight of fat in the sample}}{\text{Weight of the dry sample}} \times 100$$

vi. *Total Carbohydrates*

Total carbohydrate content was estimated by the difference between 100% and the sum of values for moisture content, fat, protein, crude fiber and ash.

$$\% \, Carbohydrate = 100\% - (\% \text{ moisture } + \% \text{protein } + \% \text{ fat } + \% \text{ ash})$$

vii. *Gross energy value*

The gross energy value was determined using standard factors of 4.00, 4.00, 9.00, and 2.00 kcal/g, for crude protein, total carbohydrates, crude fat and dietary fibre respectively (Jiang *et al.*, 2014). The calculated energy values were summed up to give gross energy values.

viii. *Heavy Metals Analysis*

The determination of Lead and cadmium followed AOAC (2000), Method 985.35. Two grams of sample were wet-ashed by dissolving in 5 ml concentrated hydrochloric acid (HCl) and heated gently on a hotplate in a fume hood for 30 min. The digested solution was cooled and conc. HNO_3 (2 ml) added and reheated for three minutes. The mixture was filtered using whatmans 42:2.5µm filter paper after cooling. The filtrate was then transferred into measuring flask (100 ml) and deionized water was added to the mark. The nitrate salts of Pb (II), Cd (II), and carrier element Cu (II) were dissolved in 1% (w/w) HNO_3 to produce stock solutions (1000 mg/L) of the metals. Prior to application, the stock solutions were diluted to provide the standard solutions for the metals. The calibration curve was obtained by diluting the stock solutions with the standard solutions in 1 $molL^{-1}$ HNO_3 (Figure 4.2). Analysis was done using the atomic absorption spectrophotometer (AAS). The specific wavelengths was 283.3nm for Lead and 228.8nm for cadmium.

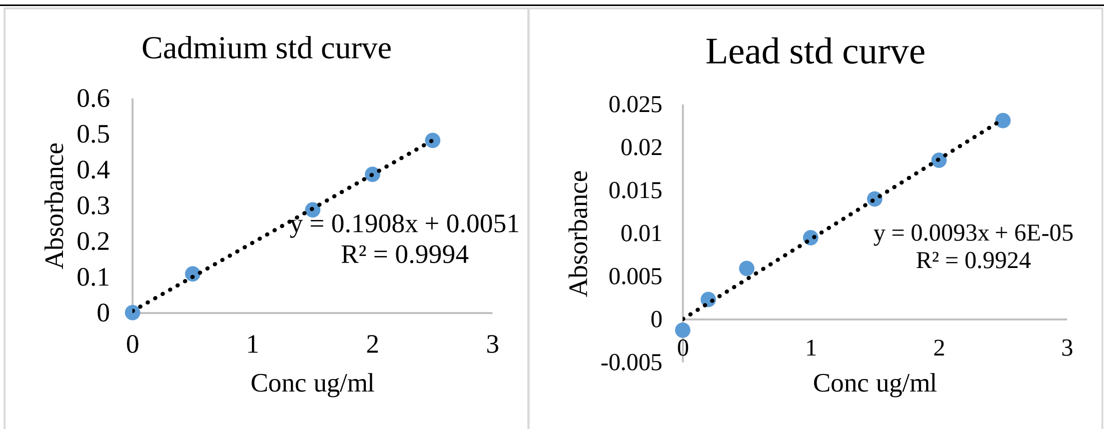


Figure 4.2: Calibration curves for Lead and Cadmium Concentrations

4.2.7 Determination of In vitro Protein Digestibility (IVPD)

Modifications were made to the methodology for multi-enzyme digestion as reported by (Recharla *et al.*, 2019). Sample (2 g) was precisely weighed and placed in a conical flask; 25 ml of 0.1 M phosphate buffer at pH 6 and 10 ml of 0.2 M HCl were added, and the pH was adjusted to 2 using 1 M HCl or NaOH solution. The sample was subsequently digested for 3 hours in a 37 °C water bath with 1ml of freshly prepared solution of pepsin -Sigma P7000-25G; activity 250 units/mg solid (Sigma-Aldrich Co, USA). The pH was then adjusted to 6.8 with 1 M HCl or NaOH solution. After that, 1ml of pancreatin solution containing trypsin enzyme (freshly prepared) - 50 mg/ml; 4 USP, P1750; (Sigma-Aldrich Co, USA) was added, and the mixture was incubated for 3 hours at 37 °C in a water bath. After incubation, the samples were placed in an ice bath to stop the enzyme's activity. The result of digestion (the clear supernatant) was then pipetted off using a pipette, and the residues were rinsed with distilled water and dried overnight in an oven at 100°C. The residual protein concentration was determined using the Kjeldahl method (AOAC, 2000). The digestibility of protein was calculated by dividing the difference between the total protein and the remaining protein after enzyme digestion by the total protein and expressing the result as a percentage.

4.2.8 Total Phenolic Content (TPC)

Using the method outlined by Ertekin *et al.* (2017), the total phenolic content was determined. 400 mg of sample was extracted with 20 ml of acidified methanol (1% HCl in methanol) at room temperature for one hour. Three replicate supernatants were obtained after samples were centrifuged at 2060 ×*g* for 20 min (Model 5804, Eppendorf, Hamburg, Germany). In a 50 ml volumetric flask, 1 ml of sample extracts were mixed with 2.5 ml of Folin-Ciocalteu phenol reagent, followed by the addition of 7.5 ml of 20% (w/v) sodium carbonate within 8 minutes. The standard curve was generated using gallic acid as the standard (Figure 4.3), and the total phenol content was reported in milligrams of gallic acid equivalents per gram (GAE). The flask was filled to capacity with distilled water, sealed, and the contents were mixed thoroughly. In addition, sample blanks were also prepared. The absorbance at 765 nm was read using a UV/VIS Spectrophotometer (model PharmaspecUV-27 1700, Shimadzu, Japan) after the flasks were left at room temperature (25°C) for 2 h.

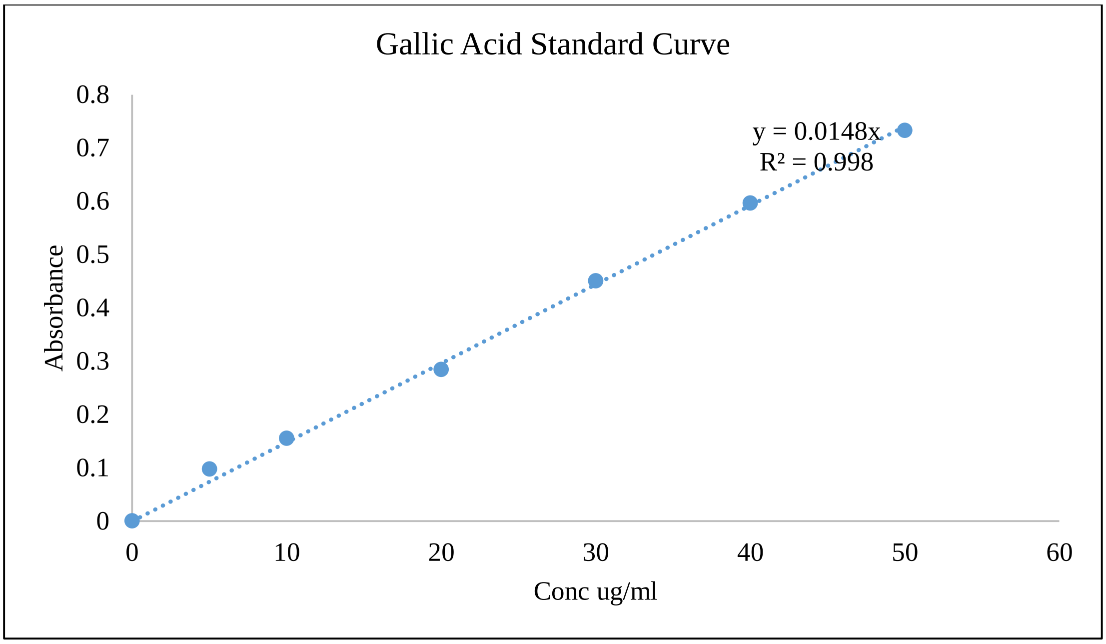


Figure 4.3: Calibration Curve for Gallic Acid Standard.

4.2.9 Statistical Analysis

The PROC GLM procedure of Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.1 was used to analyse the data obtained. The statistical evaluation employed a 4×4 factorial arrangement in a completely randomized design (CRD). A significance test was performed using an analysis of variance (ANOVA) at a 5% significance level. The separation of means was performed using Tukey's Honestly significant difference (HSD) technique. The results are expressed as mean ± standard deviation from three replication measurements.

4.3 Results and Discussion

4.3.1 Effect of Compositing Pre-Gelatinized Taro with Soybean Flour on the Proximate Composition of Snack Bars.

Table 4.2 shows the results of the proximate analysis. Compositing pre-gelatinized taro with soybean flour had significant difference on the proximate parameters of the developed snack bars ($p<0.05$). The moisture content of the snack bars was in the range of 4.14-4.65%. Snack bars containing raw soybean flour (RST) had the highest moisture content while those containing malted-roasted soybean flour (MRST) had the least. This could be attributed to the fact that raw soybean flour may have had a higher moisture content as compared to the malted-roasted soybean flour in which the moisture may have been further lost during the roasting process. Reduced moisture level in the snack bars implies reduced water available for microbial growth and activity hence, safety and prolonged shelf-life. It also confers a crunchy texture and low bulk density to the snack bar.

The ash content in the snack bars ranged between 0.7% and 1.56%, with MST1 0.7±0.34% having the least. The presence of minerals is indicated by the ash content of the food. Noor Aziah *et al.* (2012) obtained a similar range of results, i.e., 0.82-1.28% ash content and 1.56-1.95% for cookies incorporated with mung beans and chickpeas. Also, Atobatele and Afolabi (2016) reported ash content of 1.00% to 1.82% for cookies baked using a blend of soybean and corn flour.

Dietary fibre is lignin plus indigestible polysaccharide plant components. Typically, they are divided into soluble and insoluble dietary fibres. Consumption of dietary fibre has several health benefits, including moderating blood lipids, regulating glucose absorption and insulin production, and reducing constipation (Feyera, 2020). The percentage of crude fibre of the snack bars was in the range of 1.02% to 1.68%. MRST1 had the highest fibre content (1.68±0.01), while RST2 had the least (1.02±0.03). Ayo *et al.* (2014) reported a range of 1.12-1.4% crude fibre content for biscuits made from malted soybean and ocha flour composite. According to Alcantara *et al.* (2013), pectin and esterification levels in taro and soy flour may be reduced by high-temperature procedures such as baking and boiling, thus reducing their dietary fibre content, although this has no nutritional significance. This can explain the low crude fibre content generally obtained for the snack bars.

The crude protein content ranged from 3.39-14.84%, with the control PRGT having 3.39±0.12 and MST4 having 14.84±1.11. Increasing the proportion of soybean flour; 10%, 20%, 30%, and 40%, respectively, resulted in a considerable increase in the average protein content. The incorporation of raw soybean flour increased the protein content by 96.17%, 111.21%, 189.68%, and 206.78%, respectively. Malted soybean increased it by 68.73%, 173.75%, 280.83%, and 337.76%. Roasted soy increased protein levels by 55.75%, 78.76%, 178.47%, and 195.58%, while malted-roasted soybean increased the protein levels by 103.54%, 138.35%, 202.95%, and 249.49% respectively. These increases can be credited to the high protein content of soybeans which can be as high as 43% (Ronoh *et al.*, 2017).

Overall, composition with malted soybean flour resulted in the highest protein increase, while roasted soybean flour resulted in the least increase. Changes in the chemical composition of malted and sprouted foods result from enzyme activity during malting or change in composition caused by the degradation of other components. Ahure and Ejoha (2020a) and Wichamanee and Teerarat (2012) posit that increased crude protein content during malting is linked to protease enzymatic activity. Protein is degraded and hydrolysed during proteolysis, resulting in smaller amino peptides that are amenable to analysis and detection (Mann, 2003), a theory that other researchers have supported. For example, Agu *et al.* (2020) obtained a high protein content of 11.08% for biscuits made from malted bambara groundnut-ocha composite flour, which is comparable to the results of this study. Moreover, Ayo *et al.* (2014) also documented an increase of 5.99-16.78% for biscuits made from blends of up to 50% of malted soybean and ocha flour. This is the desired effect for complimentary formulations as the protein level in the snack bars conformed to a minimum protein content of 10% as recommended by FAO/WHO (Lupton *et al.*, 2002). During roasting, the endosperm complex is broken down, allowing the stored protein to be released (David *et al.*, 2022). However, some proteins may have been used up in the Maillard reaction due to the high roasting and baking temperatures (Marčiulionytė *et al.*, 2022). This may explain why low protein levels were obtained in the taro-roasted soybean composite flour-based snack bars.

Fat is an essential constituent of snack bars, providing energy and enhancing palatability. The crude fat content ranged from 1.1% to 11.54%, with the control PRGT having 1.1 ±0.14 and MST4 having 11.54 ±0.86. The mean value trend showed a significant increase in the crude fat content with the increasing proportion of soybean flour substitution; 10%, 20%, 30%, and 40%, respectively. The incorporation of raw soybean flour increased the fat content by 257.27%, 348.18%, 516.36% and 721.82%, respectively. Malted soybean increased it by 217.27%, 410.91%, 630% and 949.09%, respectively. Roasted soy increased the fat level by 189.09%, 245.55%, 387.27% and 703.64% respectively, while the addition of malted-roasted soybean increased the fat levels by 245.45%, 406.36%, 837.27% and 929.09% respectively.

Generally, the composition with malted soybean flour also increased crude fat content (3.49-11.86%), while raw soybean flour resulted in the least increase (1.1-9.04%). This could be attributed to the alternations of constituents of the soybeans during the malting process such starch, protein and fibre. The results are buttressed by other researchers who have observed parallel phenomena. Researchers Kayembe and van Rensburg (2013) found out that malted soybeans also had increased lipid content. Ahure and Ejoha (2020b) also observed a progressive increase in crude fat levels in the range of 12.04-18.99% for cookies made from malted soybean and carrot flour blend. The results also contradict findings from other researchers, such as Adelekan *et al.* (2013); Ha *et al.* (2017) and Onwurafor *et al.* (2020), who observed a reduced crude fat content in the products made from malted legumes. An anomaly that may be attributed to a spike in the activity of lipase enzymes that converted fat into fatty acids during malting (Asuk *et al.*, 2020). This results also fall within the reported limit by Ahure and Ejoha (2020b) that the percentage of fat in food products should not exceed 25%, as levels above this threshold may contribute to rancidity, affecting both the sensory and shelf life properties of the product.

Carbohydrates have diverse physiological impacts that are essential for good health. They serve as the principal energy source for majority of the population. Results indicate a reduction in carbohydrate content with increased proportion of soy flour substitution. The reduction in total carbohydrate when compositing was done using raw soybean flour was in the range between 7.2% and 17.227%. Malted soybean decreased it by 4.54% to 24.90%. Roasted soybean decreased the level by 4.66% to 16.30% and the addition of malted-roasted soybean decreased the levels by 7.27% to 21.00%. The control (PRGT) had the highest total carbohydrate content of 88.57±0.34% because taro flour contains 70-80% starch on DM basis (Melese *et al.*, 2015). MST and MRST snack bars registered the highest decrease in carbohydrate levels. This can be explained the action of the amylase enzyme during the malting process, which reduces the starch component into simple sugars and maltodextrin molecules (Asuk *et al.*, 2020). The findings of this research are consistent with those of other studies when soybean and other legumes were substituted in the product (Afifah *et al.*, 2022; Farzana & Mohajan, 2015; Rapando *et al.*, 2020). The decrease in total carbohydrate content may also be ascribed to the reduced carbohydrate content of added soy flour (29%) (USDA, 2018). The snack bars' total carbohydrate content was within the recommended dietary allowance (RDA) range of 45% to 65% for carbohydrates in foods (IOM, 2002; Trumbo 2005).

Gross food energy is the caloric value that can be obtained from a portion of food through oxidation. The highest energy quantity is derived from fat oxidation (9 kcal/g). There was a progressive increase in energy values with the inclusion of soybean flour. Substituting with raw soybean flour increased the energy value content by 4.04-9.4%. Malted soybean increased it by 3.70-13.53%. Roasted soybean increased the level by 2.46-10.09%, and the addition of malted-roasted soybean increased the levels by 3.44-13.34%. Farzana and Mohajan (2015) and Jariyah *et al.* (2018) also reported a similar trend. High caloric food intake is essential for conserving proteins for tissue repair and bodybuilding and minimizing its diversion for energy provision. These energy levels meet the minimum FAO/WHO recommendation for supplementary feeding for children (400kcal) (Commission & Organization, 1994). Additionally, compared to the standard for an emergency food product (EFP), the snack bars fulfil approximately 90% of the requirement (233kcal/50g bar) (IOM, 2002).

Table 4.2: Proximate Composition of Pre-gelatinized Taro-Soybean Flour-Based Snack Bars.

SAMPLE	% Moisture Content	% Ash Content	% Crude Fibre	% Crude Fat	% Crude Protein
PRGT	$4.42^{abcd}\pm0.06$	$1.06^{abc}\pm0.11$	$1.46^{b}\pm0.03$	$1.1^{h}\pm0.14$	$3.39^{i}\pm0.12$
RST1	$4.5^{abc}\pm0.09$	$1.12^{abc}\pm0.09$	$1.61^{a}\pm0.01$	$3.93^{fg}\pm0.27$	$6.65^{fgh}\pm0.16$
RST2	$4.32^{bcde}\pm0.02$	$1.1^{abc}\pm0.18$	$1.02^{h}\pm0.03$	$4.93^{ef}\pm0.13$	$7.16^{fg}\pm0.33$
RST3	$4.54^{ab}\pm0.09$	$1.28^{abc}\pm0.27$	$1.35^{cd}\pm0.0$	$6.78^{cd}\pm0.19$	$9.82^{d}\pm0.21$
RST4	$4.54^{ab}\pm0.02$	$1.41^{ab}\pm0.08$	$1.35^{cd}\pm0.0$	$9.04^{b}\pm0.39$	$10.4^{cd}\pm0.22$
MST1	$4.44^{abcd}\pm0.09$	$0.7^{c}\pm0.34$	$1.1^{gh}\pm0.02$	$3.49^{g}\pm0.14$	$5.72^{gh}\pm0.14$
MST2	$4.38^{bcde}\pm0.08$	$1.26^{abc}\pm0.13$	$1.3^{de}\pm0.01$	$5.61^{de}\pm0.41$	$9.28^{de}\pm0.95$
MST3	$4.36^{bcd}\pm0.09$	$1.31^{abc}\pm0.11$	$1.48^{b}\pm0.00$	$8.03^{bc}\pm0.56$	$12.91^{b}\pm0.7$
MST4	$4.14^{e}\pm0.22$	$1.56^{a}\pm0.13$	$1.4^{bc}\pm0.00$	$11.54^{a}\pm0.86$	$14.84^{a}\pm1.11$
RDST1	$4.65^{a}\pm0.08$	$1.2^{abc}\pm0.37$	$1.26^{def}\pm0.01$	$3.18^{g}\pm0.02$	$5.28^{h}\pm0.36$
RDST2	$4.21^{de}\pm0.07$	$0.98^{abc}\pm0.06$	$1.04^{h}\pm0.04$	$3.9^{fg}\pm0.12$	$6.06^{gh}\pm0.39$
RDST3	$4.28^{cde}\pm0.1$	$0.83^{bc}\pm0.01$	$1.23^{ef}\pm0.02$	$5.36^{e}\pm0.38$	$9.44^{de}\pm0.13$
RDST4	$4.47^{abc}\pm0.02$	$1.12^{abc}\pm0.38$	$1.43^{bc}\pm0.1$	$8.84^{b}\pm0.08$	$10.02^{d}\pm0.59$
MRST1	$4.31^{bcde}\pm0.02$	$1.18^{abc}\pm0.24$	$1.68^{a}\pm0.01$	$3.8^{fg}\pm0.19$	$6.9^{fg}\pm0.67$
MRST2	$4.36^{bcde}\pm0.02$	$1.00^{abc}\pm0.06$	$1.17^{fg}\pm0.01$	$5.57^{de}\pm0.31$	$8.08^{ef}\pm0.33$
MRST3	$4.38^{bcde}\pm0.03$	$1.27^{abc}\pm0.2$	$1.16^{fg}\pm0.02$	$8.11^{bc}\pm0.13$	$10.27^{cd}\pm0.33$
MRST4	$4.42^{abcd}\pm0.11$	$1.25^{abc}\pm0.18$	$1.26^{def}\pm0.04$	$11.32^{a}\pm0.9$	$11.78^{bc}\pm0.72$

Key: Values are mean±standard deviations**.** The superscript letters along the column are mean separation showi means in the same column with the same superscript letter are not significantly different. RST1;RST2;RST3;RST4;MST1;MST2;MST3;MST4;RDST1;RDST2;RDST3;RDST4;MRST1;MRST2;MRST3;MRST4 shown in Table 4.1.

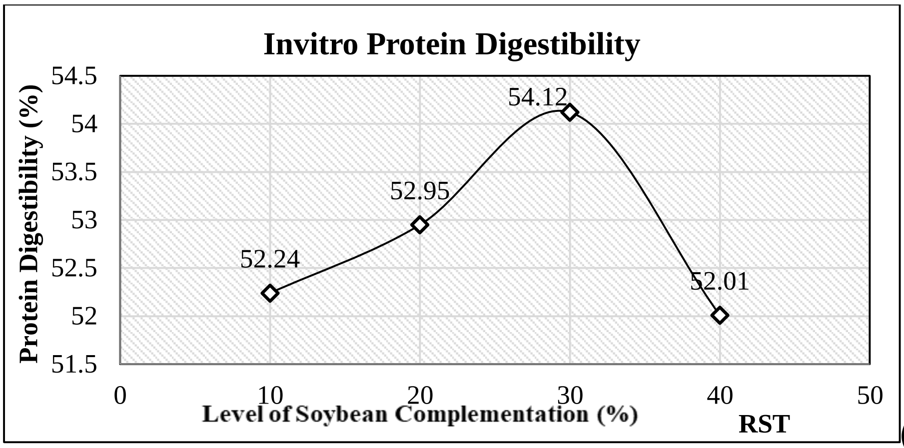
4.3.2 Effect of Compositing Pre-Gelatinized Taro with Soybean Flour on the Lead and Cadmium Content of Snack Bars.

Heavy metal contamination poses threat to public health due to bioaccumulation toxicity. They are ubiquitous and can be absorbed in foods, thus needing to be eliminated or reduced through processing. The mean values for heavy metals in raw taro flour was 0.928±0.066 mg/kg and 0.720±0.052mg/kg for Lead (Pb) and Cadmium (Cd) respectively while 0.035±0.001mg/kg of Lead was detected in pre-gelatinized taro snack bars. However, neither Pb nor Cd was detected in the taro-soybean composite flour-based snack bars. Lead binds to specific trace elements and dissolves rapidly in water, tubers are able to take up lead from the soil water in which they are grown. Consequently, the Pb in taro flour may be hydrophilic and readily soluble in water during boiling resulting reduction of Lead content through leaching (Lee *et al.*, 2020). According to the findings of the research conducted by Perello *et al.* (2008) on the influence of various cooking processes on the concentration of cadmium, arsenic, lead and mercury in foods, steaming and baking result in a significant decrease in the levels of these elements. This may explain why there was no trace of these elements found in the baked snack bars. The study is also backed up by Inobeme *et al.* (2020) and Lee *et al.* (2020), who recommend steaming, boiling, and blanching to reduce the heavy metal levels in food for safety.

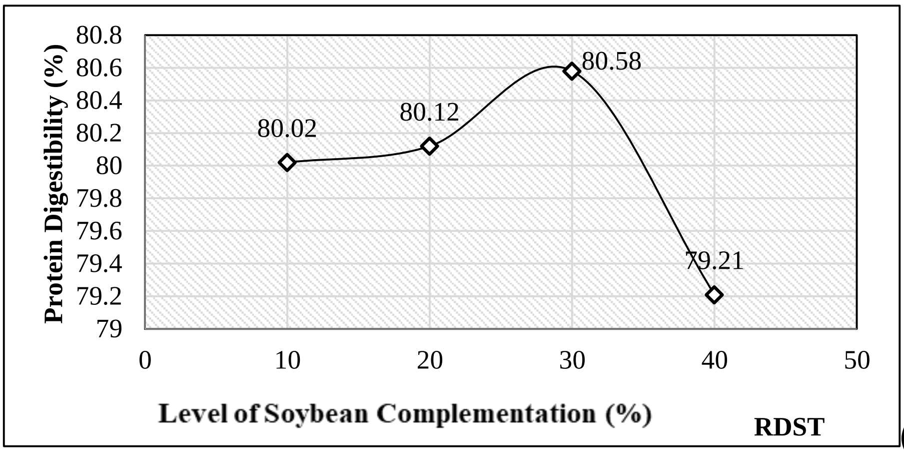
4.3.3 Effect of Compositing Pre-Gelatinized Taro with Soybean Flour on Snack Bars' Apparent Invitro Protein Digestibility.

Figure 4.3 illustrates the snack bars' apparent *invitro protein digestibility* (*IVPD*). There was a significant difference in the apparent *IVPD* at ($p<0.05$). Snack bars with raw soybean flour had the lowest digestibility (52.01-54.12%) which translates to a decrement in *IVPD* from 13.94% to 17.30%. Substitution with malted soybean increased it by 21.47% to 29.96%. Roasted soybean increased the level by 25.95% to 28%, and the addition of malted-roasted soybean increased the levels by 38.86% to 43.09%. The improvement of *IVPD* in malted, roasted and malted-roasted soy-based snack bars can be attributable to increase in globulin and albumin soybean proteins (Qin *et al.*, 2022). These proteins become more digestible due to the degradation or reduction of anti-nutrients such as trypsin inhibitors which tend to interfere with the activities of both pepsin and trypsin enzymes (Agume *et al.*, 2017) as a result of malting and roasting.

Roasting can also cause conformational changes in the protein structures by denaturation exposing the sites for proteolysis (Syeunda *et al.*, 2021). Anyango *et al.* (2011b), Ketnawa and Ogawa (2021), Natabirwa *et al.* (2020) and Nkama *et al.* (2015) also noted a significant increase in *IVPD* with the inclusion of either malted, roasted, or boiled legumes in their products. When compared to other processing methods, the values obtained for apparent *IVPD* in this study are in close range with *IVPD* for ultrasound (78.82-84.03%), and microwave (84.89-93.03%) processed soy proteins (Vanga *et al.*, 2020). A progressive trend was also observed for the inclusion of soybean from 10-30% after which the apparent *IVPD* levelled off at 40%. This phenomenon can be explained by the enzyme (Michaelis-Menten) kinetics, in which an increase in substrate concentrations (protein) increases the rate of enzyme reaction considerably up to a maximum value, then decrease due to substrate inhibition at higher substrate concentrations (Liu & Shijie, 2017). Substrate inhibition has been reported by other scholars such as (Qian *et al.*, 2011; Robinson, 2015). This implies that the best level for soybean flour complementation is up to 30%, backing a theory by Alamu *et al.* (2016).



(a)



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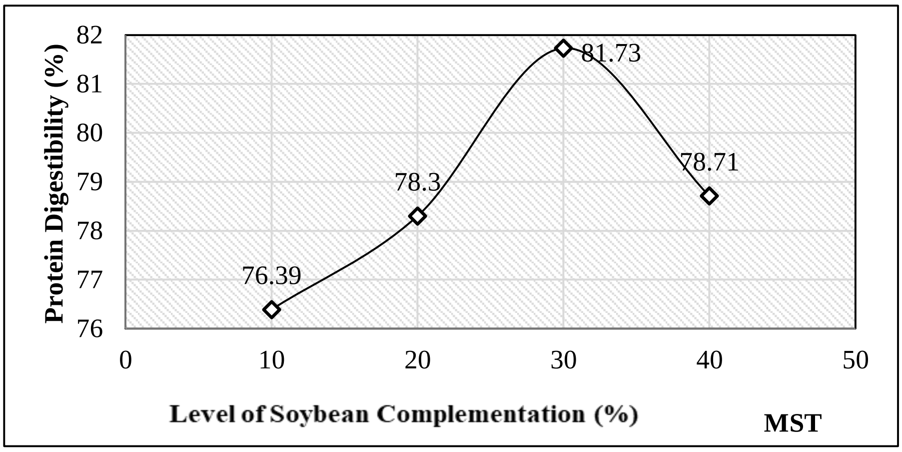

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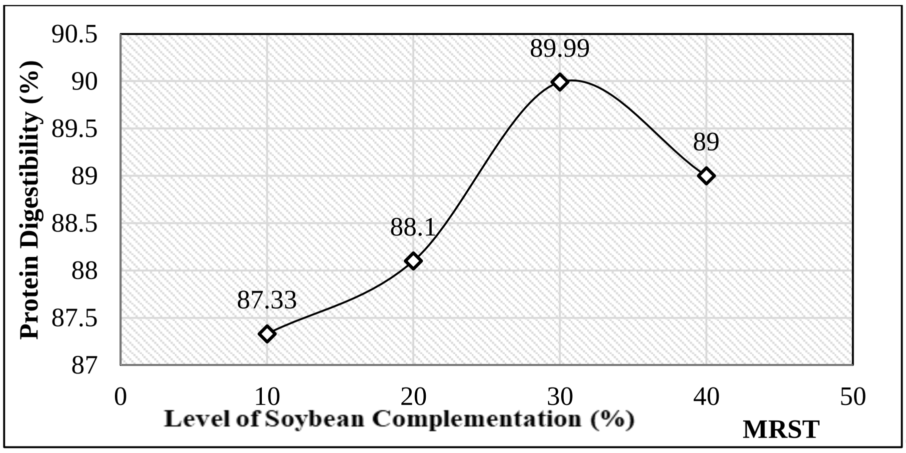


(d)

Key: Values are mean±standard deviations**.** The superscript letters along the line graph are mean separation showing significant difference at (P<0.05); graph with the same letter are not significantly different. RST1;RST2;RST3;RST4;MST1;MST2;MST3;MST4;RDST1;RDST2;RDST3;RDST4;MRST1;MRST2;MRST3

Figure 4.4: Graphs showing the Percentage of Protein Digestibility of the Different Snack Bars

4.3.4 Effect of Compositing Pre-Gelatinized Taro with Soybean Flour on the Total Phenolic Content of Snack Bars.

The total phenolic contents of the snack bars are present in Table 4.3 (c). Phenolic compounds are secondary metabolites and natural antioxidants with multiple health benefits (Singh *et al.*, 2022). These phenolic chemicals, often known as polyphenols, contain a variety of components, including flavonoids, phenolic acids, antioxidants, and anthocyanin. Foods derived from plants are rich in polyphenols and flavonoids, having antioxidant and nutraceutical characteristics (Lin *et al.*, 2016). Antioxidants also enhance the oxidative stability of products. Total phenolic in the snack bars increased significantly with an increased proportion of soybean flour inclusion. Complementation with raw soybean flour increased the phenolic content by a range of 3.37-41.91%. Malted soybean increased it by 11.65-74.13%. Roasted soybean increased the level by 9.37-60.39% and the addition of malted-roasted soybean increased the levels by 22.85-70.56%. The highest increment resulted from substitution with malted and malted-roasted soybean flour. In the study of the phenolic content in quinoa seed, soy and red kidney beans, Carciochi *et al.* (2016), Ha *et al.* (2017) and Winarsi *et al.* (2020) respectively, attributed the increment in phenolic level to malting and roasting which contradicts the findings of Syeunda *et al.* (2019) who noted a decrement. The activity of endogenous enzymes, such as esterase produced during the malting process, causes the release of the polyphenols bound initially in the seed matrix or through biosynthesis (Adetokunboh *et al.*, 2022). Moreover, roasting also disrupts the cell wall, consequently liberating the previously glycosylated or esterified polyphenols. It's possible that the production of Maillard reaction products like melanoidins while baking also impacted on the increased overall phenolic content (Hassan *et al.*, 2021). However, the high roasting and baking temperatures may also lead to the degradation of some thermally unstable phenolic compounds, which may explain why there was only a moderate increment with the inclusion of roasted soybean (Abedelmaksoud *et al.*, 2021; Bobková *et al.*, 2020).

Table 4.3 The Total Phenolic Content of Snack bars

Sample	Total Phenolic Content (mg(GAE)/100g)
RT	45.34^{j} ±0.31
RST10	46.87^{ij} ±0.21
RST20	57.67^{fg} ±0.12
RST30	59.16^{ef} ±0.16
RST40	64.34^{d} ±0.97
MST10	50.62^{h} ±0.04
MST20	66.59^{cd} ±1.62
MST30	67.08^{c} ±0.13
MST40	78.95^{a} ±0.63
RDST10	49.59^{hi} ±2.25
RDST20	61.12^{c} ±0.46
RDST30	67.78^{c} ±0.13
RDST40	72.72^{b} ±0.72
MRST10	55.7^{g} ±0.18
MRST20	66.18^{cd} ±0.41
MRST30	68.09^{c} ±0.07
MRST40	77.22^{a} ±1.61

Key: Values are mean±standard deviations**.** The superscript letters along the column are mean separation showing significant difference at ($P<0.05$); means in the same column with the same superscript letter are not significantly different.

RST1;RST2;RST3;RST4;MST1;MST2;MST3;MST4;RDST1;RDST2;RDST3;RDST4;MRST1;MRST2;MRST3;MRST4-refers to the blending proportions as shown in Table 4.2.

4.4 Conclusion.

This study demonstrates that it is feasible to make snack bars using lends of taro and soybean flour. All nutritional indices, especially those relating to protein, lipids, and energy, increased significantly. The snack bars' protein and energy content meets the WHO/FAO RDA for supplementary feeding. Also, the snack bars are able to fulfil approximately 90% of the requirement for emergency food products. Pre-gelatinization and baking also reduce the Lead and Cadmium present in the food. Adding malted-roasted soybean flour to the snack bars significantly improves protein digestibility. The study also demonstrates that soybean complementation is best done up to 30%.

CHAPTER FIVE

DESCRIPTIVE SENSORY EVALUATION AND CONSUMER ACCEPTANCE TESTING OF PROTEIN-RICH SNACK BARS DEVELOPED FROM PRE-GELATINIZED TARO (*Colocasia esculenta*) AND SOYBEAN (*Glycine max* L.) COMPOSITE FLOUR.

Abstract

Population-based research demonstrates that there has been an increasing trend in consumer snacking habits and this has led to a global rise in market for processed snack foods. As a result, there is a great demand for new, wholesome snack food products, which drives industry efforts into research and development focused on these products. The objective of this study was to formulate a nutritious acceptable snack bar by compositing pre-gelatinized taro and soybean flour, to evaluate the sensory attributes and consumer acceptability. These bars were evaluated by a consumer panel (n = 40) and a descriptive panel (n = 9). The results from the descriptive analysis showed a significant effect on the intensity of sensory attributes of the developed snack bars. Compositing with roasted soy flour resulted in a snack bar with the highest colour intensity and highly perceivable aroma. In contrast, adding raw soy flour resulted in less colour intensity and the highest beany flavour intensity. Compositing with malted and malted-roasted soy flour resulted in less brittle snack bars. Generally, snack bars made from taro-raw soy composite had the highest mean acceptability value for consumer tests and corresponded to 'like slightly' on the 7-point hedonic scale. In conclusion, pre-gelatinized taro-soy flour composite can be used to develop sensory and consumer-acceptable snack bars that are rich in protein and can help curb cases of protein-energy malnutrition and simultaneously increase the utilization of both taro and soybeans.

5.1 Introduction

Globally, today's population is defined by fast-paced lifestyle, leading to remarkable changes in consumer food preferences and consumption patterns. As a response to these changes, population-based studies have shown an increased trend in the consumption of 'fast foods' (Omwamba & Mahungu, 2014). Food processors are therefore tasked with the burden to meet the busy consumers' preference who value affordability, convenience, palatability, and perceived health in their food but have little time to cook elaborate meals such as snacks (Mattes, 2018). Convenience encompasses people's desire to save time and cognitive effort while engaging in the consumption process (Nakano & Washizu, 2020).

The snack industry has gained a foothold and is an important contributor to the global convenience food market. The convenience food industry is expected to increase from 2011's $1.1 trillion to 2016's $1.3 trillion, a growth rate of 3.2%. (Kelly, 2019). In her study Momanyi *et al.* (2020) postulated that the snack food industry around the world is expected to grow to $630.00 billion by the year 2020. Snacking has become an integral part of most of the world's population's eating habits. As hypothesized by Mattes (2018) and Momanyi *et al.* (2020), on average, people in the Mediterranean and Nordic regions get 14% and 29% of their daily energy from snacks.. Also, Hess *et al.* (2017) purports that in America, about a quarter of the calories consumed by children and teenagers come from snacks. Sub-Saharan Africa, like many other developing countries, has a steadily rising prevalence of snacking compared to the West. These snacks include potato or tortilla chips, extruded snacks, snack bars such as protein bars, granola bars, and cereal bars.

Snack bars (SB) are gaining popularity as part of human diets because of their ease of use and versatility (Suhem *et al.*, 2017). Snack bars are ready-to-consume food items processed by mixing various dry ingredients and combined using a binder (Rejeki *et al.*, 2019). They are exceptional high nutritive value convenient foods that can supply a substantial amount of essential nutrients needed; protein, carbohydrates, fats, vitamins and abate hunger. Snack bars can be either supplementary or complementary food (Herawati *et al.*, 2019). Initially, SB was introduced as an energy source for athletes. However, they have rapidly attracted the attention of other consumers. According to Constantin and Istrati (2018), the International Markets Bureau market indicators reports that SB is additionally significantly impacted by the following factors: satisfying a sweet tooth; saving time; using it as a source of energy; using it for losing weight; and nourishment; dietary fibre, protein, and vitamins contents.

In children's and adult diets, snack bars are increasingly present. Therefore, they can provide an excellent avenue for delivering the required nutrient to help curb malnutrition as they are considered "fun food" because of their sensory attributes (Lucas *et al.*, 2020). Snack bars made from taro and soybeans have a lot of untapped promise as a means of meeting nutritional demands and reducing food insecurity in low-resource regions. Therefore, the purpose of this research was to assess the sensory attributes and consumer acceptance of protein-rich snack bars made from pre-gelatinized taro-soy composite flour.

5.2 Materials and Methods

5.2.1 Preparation of Raw Material

Pre-gelatinized taro flour was prepared as shown in section 4.2.2 and malted and roasted soybeans were prepared as par 4.2.3. The blending of the different proportions soybeans with taro was done as per Table 4.1. Eight snack bars were selected for sensory analysis based on the criterion of protein digestibility and level of blends proportions namely RST1, RST3, MST1, MST3, RDST1, RDST3, MRST1 and MRST3. Snack bars was prepared as described in section in 4.2.5 **(**Figure 5.1(a) & (b)**)**

Figure 5.1(a): Flow chart for processing of

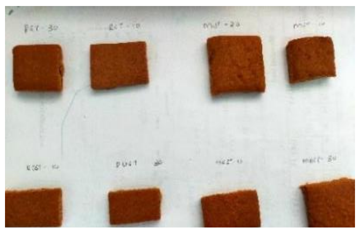


Figure 5.1 (b): snack bars developed from different ratios of Taro

5.2.2 Descriptive Sensory Analysis

i. Selection and Screening of the panel

The panel was selected and screened in accordance with the methods outlined by Syeunda *et al.* (2019). The descriptive sensory panel (invited via phone, email, and notices) was comprised of students and faculty from the Department of Dairy and Food Science and Technology at Egerton University who were willing to consume the snack bars, had some experience with descriptive sensory evaluation, and did not have any known food allergies. Seventeen people responded and attended the orientation session. Six individuals had experience with sensory evaluation. Nine out of the seventeen confirmed their availability. Standard screening procedures were used to assess the sensory acuity of our nine panellists by having them identify the four basic flavours (sweet, salty, bitter, and sour) and the sensory qualities that characterize the flavour, texture, and appearance of several snack bars. The final panel of nine assessors included six experienced individuals and three novices.

ii. Training of the panel

According to the generic descriptive method outlined by Meilgaard *et al.* (2006), the panel was trained over the course of four days, with each day consisting of two-hour sessions. During the training phase, panellists were repeatedly briefed on the characteristics of snack bars. For the purpose of assessment, a vocabulary of descriptive terms and scale anchors (lexicon) was put together and defined and a consensus reached. Panelists then refined how to rate the intensity of each product's qualities/attributes and to achieve idea alignment throughout the pane in multiple group practice sessions.

iii. Lexicon Development

In two 3-hour sessions, the qualities and descriptive references were developed by the panellists for the samples. Basic qualities were developed and refined using the literature review, prior experiences, and panellist comments. Regarding the appropriateness of qualities, description, and references, the descriptors were developed following the example of a consensus technique (Chambers, 2018; Meilgaard *et al.*, 2006). The final descriptor list (Table 5.1) was determined after compiling a product reference frame to develop terms, reviewing references, and analysing examples. Ciccone *et al.* (2020), De Godoy *et al.* (2020), Kumar (2020) and Tran *et al.* (2019), among others are just a few examples of recent research studies that use a similar approach.

iv. Sensory Evaluation

Each panelist was presented with the eight samples on a partitioned white plate along with a serviette, a glass of water to rinse their mouths, and a scoring sheet. Each panel's samples were assigned a unique three-letter code, and the presentation order was randomized (Appendix II). The panelist evaluated the intensity of the sensory attributes based on the seventeen descriptive terms under the categories of appearance, aroma, taste & flavour, aftertaste, and texture as represented in the lexicon (Appendix II) (Civille & Carr, 2015; Meilgaard *et al.*, 2006).

5.2.3 Acceptance Testing

Snack bar acceptance among consumers was tested using methods detailed by Civille and Carr (2015), Kavaya *et al.* (2019) and Meilgaard *et al.* (2006). The Guildford Institute at Egerton University's Department of Dairy and Food Science & Technology served as the setting for the sensory evaluations. The general acceptability, colour, flavour, texture and taste was rated on a 7-point hedonic scale (where 7 equal like extremely, 6 equal like moderately, 5 equal like slightly, 4 equal neither like nor dislike, 3 equal dislike slightly, 2 equal dislike moderately, 1 equal dislike extremely) (Appendix II). The test was carried out with the assistance of forty semi-trained panellists. The panelists assessed the samples in white-light-illuminated individual testing booths, where they recorded their sensory data.

Table 5.1: Descriptive Sensory Lexicon Developed by Descriptive Sensory Panel to Evaluate Taro-Soybean Composite Flour-Based Snack Bar.

Attribute	Definition	Reference	Rating Scale
Appearance			
Colour	The intensity of colour ranging from light amber/brown to dark amber/brown.	1= light brown (tiffany butter toffee) 9= dark brown (lindt 70% cocoa dark chocolate)	1= light brown 9= dark brown
Consistency	the extent of visual uniformity of the sample/level of smoothness	9= 	1= smooth 9= patchy
Density	The extent of compactness of the cross-section of the snack bar	1=  9= 	1= porous 9= compact
Surface gloss	The extent of shininess of the surface of the snack bars as result of the fat content.	1=  9= 	1= dull 9= glossy
Aroma			
Overall aroma intensity	The intensity of aroma associated with baked products	9= highly perceivable smell of baked products	1= less intense 9= more intense
Taste & Flavour			
Caramel	Intensity of flavour associated with caramelization.	1= less perceivable smell of burnt sugar	1= less intense 9= more intense

		9= highly perceivable smell of burnt sugar	
Sugary	Intensity of taste of sweetness associated with baking sugar	1= less sweet 9= very sweet	1= less intense 9= more intense
Astringency	The extent of puckering/shrinking of or drying sensation on the surface and/or edges of the lips, tongue, and mouth	1= less stringent 9= more stringent	1= less intense 9= more intense
Starchy	The extent of taste associated with high starch foods especially when raw starch is consumed.	9= extreme taste of raw flour	1= less intense 9= more intense
Beany	Intensity of flavour associated with uncooked soy beans.	9= sample containing 30% raw soybean flour	1= less perceivable 9= highly perceivable
Lingering/aftertaste	The intensity of the sensation after swallowing i.e. how long the sensation lasts in the mouth.	9= aftertaste of raw, malted or roasted soybeans (at 30%)	1= less intense 9= more intense
Texture			
Dryness	Intensity of how dry the sample is i.e. amount of saliva required to wet the sample when chewing	9= requires a lot of saliva to wet the sample	1= moist 9= dry

Cohesiveness	Intensity of how the sample particles tend to agglomerate/stay together during chewing i.e. forming a ball.	9= forms a ball like white bread made from wheat flour	1= particulate 9= cohesive
Fructurability	Intensity of the force with which the sample raptures/ degree of brittleness	9= sample containing 10% soybean	1= crumbly 9= brittle
Grittiness	The extent of small, hard particles between teeth during chew	9= many grainy particle	1= none 9= many
Particles	The extent to which particles are felt or left pericarp felt dry in the mouth after swallowing	9= sample containing 30% soybean	1= none 9= many
Stickiness	The degree to which residues adhere to the teeth during and/or after chewing.	1= does not adhere to teeth 9= extremely adheres to the teeth	1= less sticky 9= highly sticky

5.2.4 Principal Component Analysis (PCA)

From a matrix of correlations or variances-covariance, PCA can infer meaningful patterns. Using descriptive analysis, numerous dependent variables may be correlated. PCA replaces correlated original attributes with a factor by identifying correlation patterns among dependent variables. The residual variance is then used to generate the second and third group components. It offers loading and scores. The former are attribute-dimension correlations, while the later are product-dimension values. Factor loadings and factor scores are critical for interpreting dimensions and mapping products (Chapman *et al.*, 2001; Puri *et al.*, 2016). With

PCA, the dependent variable is transformed into independent dimensions, which helps to streamline the data and get rid of unnecessary descriptors.

5.2.5 Statistical Analysis.

Data obtained was analysed using the PROC GLM procedure of the Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.1 and SAS JMP. The statistical evaluation employed a completely randomized design (CRD) in a 4×2 factorial arrangement. A test significance was done by performing an analysis of variance (ANOVA) at a 5% significance level. The means separation was done using Tukey's Honestly significant difference (HSD) method. The results are expressed as mean ± standard deviation from three replication measurements.

5.3 Results and Discussion

5.3.1 Effect of Compositing Pre-gelatinized Taro with Soybean Flour on the Sensory Attributes of the Snack Bars.

From the F- values, the results show an overall significant difference in the snack bar parameters (Table 5.2). The addition of soybean (raw, malted, roasted, and malted-roasted) in the 10% and 30% to the pre-gelatinized taro gave a significant difference in colour, consistency, gloss, aroma, caramel, sugary taste, beany flavour, aftertaste, cohesiveness, and fracturability parameters. The rest of the parameters were not significantly different for the snack bars. The snack bars RDST1 (7.00±0.71) and RDST3 (6.89±0.69) had the highest colour intensity of colour while RST1 (5.11±1.05) and RST3 (5.22±0.97) had the least colour intensity. The intensity of the brown colour can be attributed to non-enzymatic reactions such as Maillard reaction during the roasting of the soybeans, which leads to the production of brown pigments (Turan *et al.*, 2015). The caramelization of the glucose syrup could have further intensified the browning during the baking of the snack bars. Rahmi *et al.* (2021) observed the same phenomenon when carrying out sensory profiles for sweet potato and soy-based snack bars and Mridula *et al.* (2007) obtained similar results (7.14) for colour when carrying out the sensory evaluations for sattu (a traditional Indian snack) made with roasted soybeans.

The aroma intensity was highly perceivable for RDST1 (6.22±0.67) and RDST3 (6.33±1.12), while MRST3 was the least perceivable. During malting, hydrolytic enzymes such as cytolytic enzymes, proteases, amylases, and lipases are activated. The amylases and proteases degrade and hydrolyse starch and protein in the soybean into fermentable sugars, peptides, and free amino acids, respectively. These are aroma compound precursors (i.e. amino components and sugars) of maillard reaction and caramelization compounds such as pyrazines (Marčiulionytė *et al.*, 2022) which happen during roasting or baking and is desirable in snacks. However, as influenced by the germination parameters, Lipases such as lipoxygenases (LOXs) which generate molecular compounds including (E,Z)-2,6-nonadienal which smells like cucumbers as well as other undesirable compounds like such as hexanal and (E)-2-nonenal which smells like green plants and cardboard respectively (Prado *et al.*, 2021). The factors may explain why the aroma intensity of MRST3 (3.11 ±1.27) may have reduced. The aroma intensity obtained for RDST1 (6.22±0.67), RDST3 (6.33±1.12), MST1 (5.33±0.87) and MST3 (5.11±1.45) are in tandem with the observation made by (David *et al.*, 2022) when evaluating the sensory quality of snacks made from a formulation consisting of malted and roasted sorghum and sesame.

For the sugary taste (sweetness) parameter compared to the rest of the snack bars, RDST3 (4.67±1.22) had the least intensity. This may be attributed to the degradation of monosaccharides during roasting, which may have led to a decrease in sweetness, an upsurge in total acidity, and generation of acetic acid, considerably reducing the overall intensity (David *et al.*, 2022). RST1 (7.11±1.69) and RST3 (7.11±1.62) had the highest intensity of beany flavour, whereas the other snack bars were not significantly different. The first step in expanding the market for snacks made from legumes to more niche demographics is to make sure those consumers like the way they taste. Some consumers don't like the "beany flavour" or aftertaste that might emerge from using beans in a variety of items. A review by Feyera (2020), for instance, indicated that the aroma score for biscuits formulated with wheat, barley and soy flour reduced with proportional complementation with soy flour in the product. Sparvoli *et al.* (2021) and Momanyi *et al.* (2020) found out that the same intensity in beany flavour when they incorporated legumes in their snacks. Fracturability refers to the Intensity of the force with which the sample raptures/ degree of brittleness or hardness. RST1 (7.78±0.67) and RST3 (7.87±0.87) were the most brittle while MST3 (5.11±1.9), RDST3 (5.22±1.72) and MRST3 (5.11±1.62) were more crumbly. This can be due to fact that roasting reduce the hardness of soybeans, as purported by Mridula *et al.* (2007) and Vasanthakaalam and Dusingizimana (2011) in their studies resulting in the reduced brittleness of snack bars

Table 5.2: Intensity of the Sensory Attributes for the Eight Taro-Soy based Snack bars

Colour	Consistency	Density	Gloss	Aroma	Caramel	Sugary	As
$5.11^{c}\pm1.05$	$5.33^{bc}\pm1.00$	$6.33^{a}\pm0.71$	$5.22^{ab}\pm0.67$	$5.56^{ab}\pm0.88$	$4.67^{b}\pm2.21$	$6.78^{a}\pm0.83$	3.7
$5.22^{bc}\pm0.97$	$5.56^{b}\pm1.24$	$6.22^{a}\pm0.83$	$5.89^{ab}\pm0.6$	$5.56^{ab}\pm1.42$	$5.78^{ab}\pm1.2$	$6.78^{a}\pm0.67$	4.6
$5.67^{bc}\pm0.71$	$5.89^{ab}\pm1.54$	$6.00^{a}\pm0.87$	$4.56^{bc}\pm0.73$	$5.33^{ab}\pm0.87$	$5.33^{ab}\pm1.32$	$6.22^{a}\pm0.97$	5.2
$5.56^{bc}\pm0.73$	$5.33^{ab}\pm1.00$	$6.67^{ab}\pm0.87$	$6.00^{ab}\pm0.87$	$5.11^{ab}\pm1.45$	$5.44^{ab}\pm1.24$	$5.89^{ab}\pm1.17$	4.0
$7.00^{a}\pm0.71$	$7.33^{a}\pm1.00$	$6.00^{a}\pm1.00$	$5.78^{ab}\pm0.83$	$6.22^{a}\pm0.67$	$6.67^{ab}\pm1.00$	$6.11^{ab}\pm1.27$	3.6
$6.89^{a}\pm0.69$	$6.11^{ab}\pm0.93$	$6.78^{a}\pm0.44$	$3.22^{c}\pm2.05$	$6.33^{a}\pm1.12$	$7.00^{a}\pm1.58$	$4.67^{b}\pm1.22$	5.0
$6.33^{ab}\pm0.71$	$3.56^{d}\pm1.13$	$6.22^{a}\pm0.97$	$6.56^{a}\pm0.73$	$4.11^{bc}\pm1.83$	$6.33^{ab}\pm1.41$	$7.00^{a}\pm0.87$	4.3
$6.11^{abc}\pm0.78$	$3.89^{cd}\pm0.93$	$6.56^{a}\pm0.73$	$5.11^{ab}\pm1.05$	$3.11^{c}\pm1.27$	$6.44^{ab}\pm0.88$	$5.67^{ab}\pm1.22$	4.6

Measured by the Descriptive Panel.

Table 5.2: Continued

Starchy	Beany	Aftertaste	Dryness	Cohesiveness	Fracturability	Grittiness	Particles
4[a] ±0.71	7.11[a] ±1.69	6.78[ab] ±0.97	6.44[a] 0.73	4.56[bc] ±1.13	7.78[a] ±0.67	5.78[a]±0.83	4.78[a] 1.86
4.78[a] ±0.97	7.11[a] ±1.62	7.00[a] ±0.87	6.56[a] 1.01	5.89[abc] 1.83	7.87[a] ±0.87	5.89[a] ±0.78	5.56[a]±0.88
4.44[a] ±1.13	4.22[b] ±1.3	5.00[c] ±0.87	6.33[a] 0.71	4.44[c] ±0.73	6.00[ab] ±1.41	6.11[a] ±0.93	5.11[a]±1.17
4.78[a] ±1.48	4.33[b] ±1.22	5.11[c] ±0.93	6.56[a]±1.33	5.00[bc]±0.5	5.11[b]±1.9	5.67[a] ±1.00	5.67[a]±0.5
4.22[a] ±1.3	3.78[b] ±0.67	5.22[bc] ±0.97	6.67[a] ±0.1	5[ab] ±1.41	6.44[ab] ±1.67	6.00[a] ±0.87	5.00[a]±1.87
5[a] ±1.32	3.11[b] ±0.93	5.33[bc] ±1.8	6.78[a] 0.83	5.11[bc] ±0.78	5.22[b] ±1.72	5.78[a] ±0.67	6.22[a]±0.67
4.44[a] ±1.24	4.44[b] ±1.59	4.11[c] ±1.27	6.89[a] 0.60	6.33[c] ±1.12	7.11[ab] ±1.05	5.78[a] ±0.83	4.89[a]±1.17
4.22[a] ±1.48	4.78[b] ±1.09	4.89[c] ±0.93	6.67[a] 0.71	7.33[a] ±1.12	5.11[b] ±1.62	5.33[a] ±0.50	5.67[a] 1.87

ues are mean±standard deviations**.** The superscript letters along the column are mean separation showing significant differen
e column with the same superscript letter are not significantly different. The scores are based on a rating scale of between 1
on 5.2.2. RST1;RST3;MST1;MST3;RDST1;RDST3;MRST1;MRST-refers to the blending proportions as shown in Table 4

5.3.2 Principal Component Analysis of the Sensory Attributes of the Snack Bars.

The data from 10 attributes (chosen using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy criterion) evaluated on the 8 snack bars were analysed using principal components analysis (PCA) to simplify their interpretation and listed in Table 5.3. To learn more about the specific primitive factors that are of crucial importance among the sensory descriptors, PCs were extracted using the maximum variance values of the descriptors. Three of the extracted principal components were chosen for further analysis because they had eigenvalues greater than one and explained 70.1% of the total variance in the data set. The results showed that PC1 with an eigenvalue of 3.53 could explain 35.33 percent of the total variation (Figure 5.3 (a)), PC2 with an eigenvalue of 2.41 could explain 24.09 percent of the variation, and PC1 and PC2 together could explain 59.42 percent of the total variation. The third PC, with an eigenvalue of 1.07, explained 10.68% of the total variance. Different principal components have been identified by a number of researchers. For example, Rios *et al.* (2020) identified two factors that explained 61.09% of the total variation when carrying out analysis on design and acceptability of multi-ingredient snack bars and Ryland *et al.* (2010) found that using micronized flaked lentils to develop snack bars led to the extraction of three principal components that accounted for 86% of the variability in the sensory attribute data.

Then, Varimax rotation was applied to these three PC such they more closely resemble the initial factors as per Lawless and Heymann (2010) as shown in Table 5.3. Correlations between principal component analysis and descriptive attribute data are visualised using varimax rotated factor loading. Only loadings with an absolute value > 0.56 (indicating a significant influence) are tabulated. Also, *Figure 5.3.2B* shows the loading plot for the correlations between sensory qualities and samples for the three PCs. Close measurements are positively associated, those negatively related are 180° apart, and those 90° apart are independent and would consequently be loaded on separate PCs (Mwove *et al.*, 2018). The attributes loaded on the first component indicate a strong correlation of the attributes with PC1. PC1 was positively correlated to beany flavour and aftertaste and negatively correlated to surface gloss, sweet taste and fracturability. PC2 was positively correlated to cohesiveness and negatively correlated to consistency and aroma.

Additionally, PC3 was positively correlated to particles and negatively correlated to brown colour. As suggested by Chapman *et al.* (2001) and Puri *et al.* (2016) one principle component can explain more than one variable. This implies that as the level of soybean complementation in taro increases, the fracturability, glossiness and sweetness in the product will decrease. This inference is in line with the observation made by Ryland *et al.* (2010), where the panelists noted decreased sweetness in the snack bars incorporated with lentils. Followed by a decrease in consistency and aroma (PC2) and the last component to be notable affected will be colour i.e. decrease in the intensity of the brown colour (PC3).

The correlation between the snack bar samples and sensory attributes showed that MRST1, RST3 and RDST3 were positively correlated and were associated with high surface gloss, sweet taste and fructurability. MST1 and MST3 snack bars were positively correlated and were associated with beany taste and brown colour this could be attributed to the fact that they both contained malted soybean (10 and 30% respectively). Aliani *et al.* (2011) and Anyango *et al.* (2011a) and also observed similar phenomena where samples containing similar ingredient that is cowpeas and flaxseeds respectively, were positively correlated. RST1, MST1 and RDST1 were positively correlated and associated based on their appearance and consistency and this could be due to the fact that these samples contained low amount of soybean flour in the blend (i.e., 10%). MRST3 was associated with high particles and aftertaste.

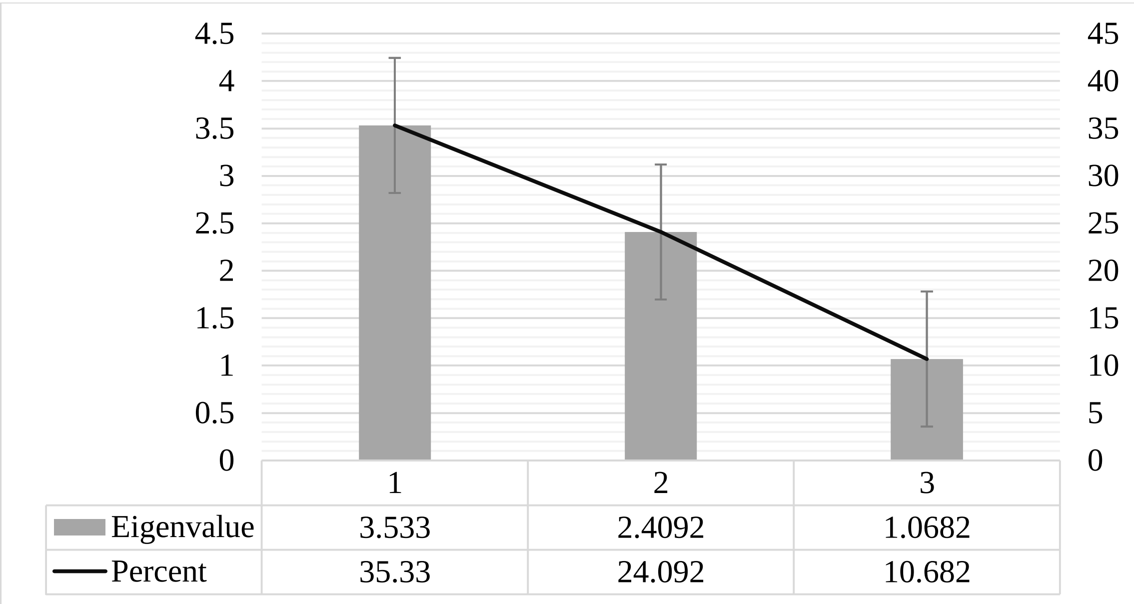
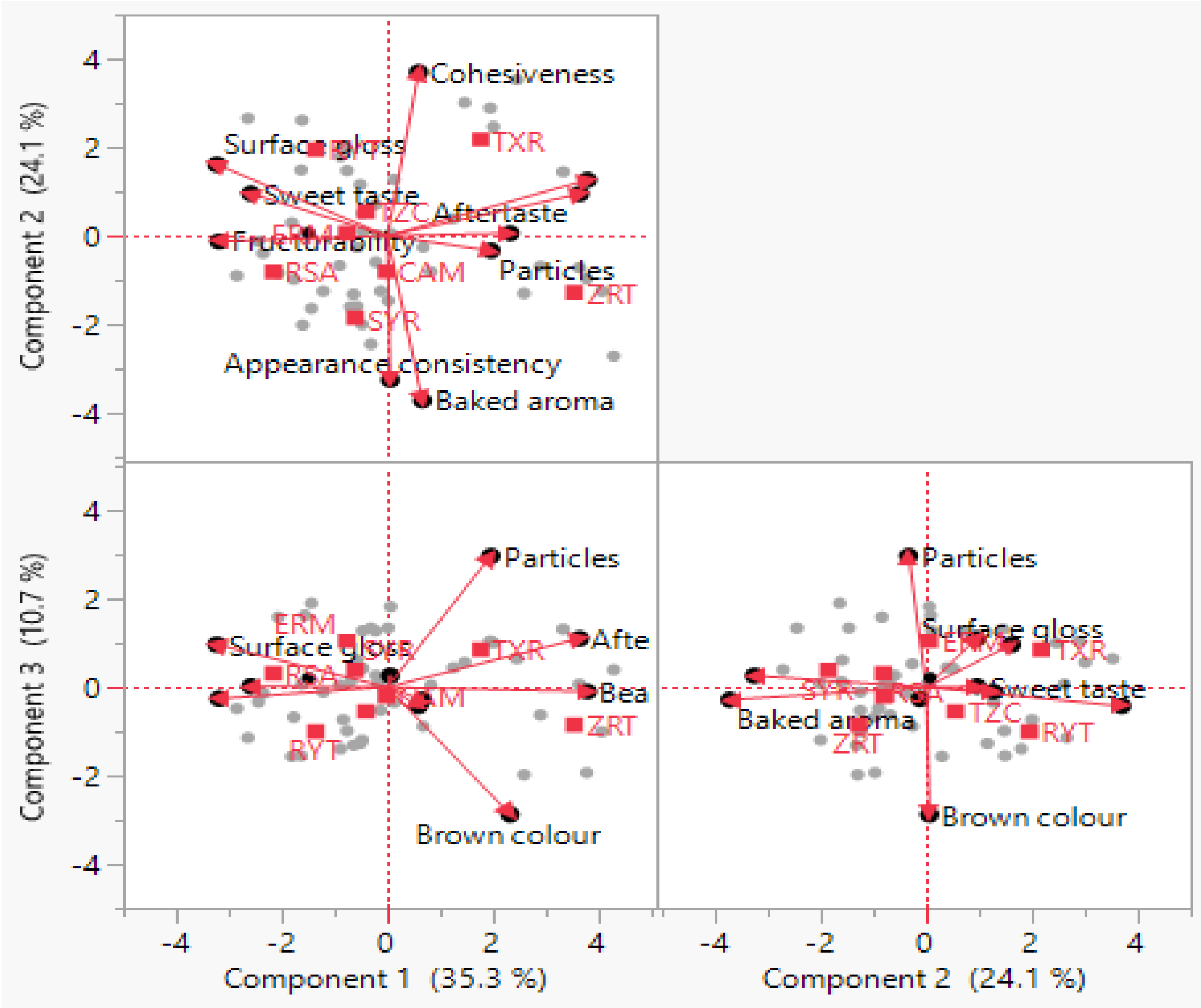


Figure 5.2: Plot showing Eigen value and percentage of three extracted principal component generated using PCA

Table 5.3: Verimax Rotated Principal Component Factor Loading for Sensory Attributes of Taro-Soy Flour based Snack Bars.

Sensory attribute	Prin1	Prin2	Prin3
Brown colour			-0.67087
Appearance consistency		-0.75870	
Surface gloss	-0.75335		
Baked aroma		-0.86831	
Sweet taste	-0.60365		
Beany taste	0.88372		
Aftertaste	0.84940		
Cohesiveness		0.86337	
Fructurability	-0.74352		
Particles			0.69254
Variance Explained[a]	35.33%	24.09%	10.68%



Key: The sample codes i.e., RSA-RST1, TZC-RST3, CAM-MST1, ZRT-MST3, SYR-RDST1, ERM-RDST3, RYT-MRST1 & TXR-MRST3. RST1;RST3;MST1;MST3;RDST1;RDST3;MRST1;MRST3-refers to the blending proportions as shown in Table 4.1.

Figure 5.3: Plot of PC1, PC2 and PC3 for the snack bars samples and sensory attributes

5.3.3 Effect of Compositing Pre-gelatinized Taro with Soybean Flour on the Consumer Acceptance of the Snack Bars.

Consumer scores for sensory acceptability of the snack bars have been presented in Table 5.4. The overall acceptability means score ranged from 5.69 to 4.42 on a 7-point hedonic scale. This indicates that the snack bars were found to fall under the category of "like slightly to neither like nor dislike". From the results, RST3 (5.69±1.36) obtained the highest overall acceptability score as compared to the other snack bars i.e., 4.67±1.33 (RST1), 5.09±1.44 (MST1), 4.58±1.39 (MST3), 5.04±1.4 (RDST1), 5.04±1.51 (RDST3), 5.24±1.54 (MRST1) and

4.42±1.62 (MRST3). Amongst the all snack bars, sensory scores of RST3 prepared with 70:30 Taro: Raw Soy composite flour has been ranked highest for most of the sensory attributes except for the colour which was not significantly different for all the snack bars i.e. 5.96±1.26 (Colour), 5.58±1.23 (Flavour), 5.13±1.59 (Texture), 5.51±1.52 (Taste), and 5.69±1.36 (Overall acceptability) than the rest of the snack bars. Further, it can be discerned that there was a general decrease in all sensory attributes with proportionate incorporation i.e., from 10% to 30% of the different soy flour.

Despite the increase in beany flavour with increased level of raw soy complementation as indicated by PC1, a phenomena that have been indicated by several researchers to be a barrier to the acceptance of legume composited foods (Anyango *et al.*, 2009; Momanyi *et al.*, 2020; Sparvoli *et al.*, 2021). The high ranking of RST3 for the sensory can be attributed to the fact that legume-based foods have a robust umami flavour. Umami, sometimes known as the "fifth taste," has been shown to increase saliva production, alleviate eating disorders, increase appetite and satiety, and improve hypogeusia (by enhancing the gustatory-salivary reflex) (Sparvoli *et al.*, 2021; Wang *et al.*, 2020). For elderly consumers whose sense of taste and smell may have weakened, this is a desirable quality, as umami has been shown to stimulate appetite. In addition, it has been shown that umami chemicals greatly reduce the sensitivity to sucrose due to competition for binding to the common receptor subunit T1R3(Shim *et al.*, 2015), which may explain the observation made in PC1 i.e. where there was perceived reduction in sweetness with incorporation of various soy flours (Anyango *et al.*, 2009).

Table 5.4: Consumer Scores for Sensory Characteristics of the Eight Taro-Soy based Snack bars.

amples	Colour	Flavour	Texture	Taste	Overall A
RST1	$5.58^{a}\pm1.25$	$4.87^{abc}\pm1.34$	$3.89^{c}\pm1.92$	$4.91^{abc}\pm1.49$	4
RST3	$5.96^{a}\pm1.26$	$5.58^{a}\pm1.23$	$5.13^{a}\pm1.59$	$5.51^{a}\pm1.52$	5
MST1	$5.78^{a}\pm1.2$	$4.82^{abc}\pm1.81$	$4.58^{abc}\pm1.44$	$4.8^{abc}\pm1.56$	5
MST3	$5.4^{a}\pm1.75$	$4.22^{c}\pm1.62$	$4.98^{ab}\pm1.37$	$3.98^{c}\pm1.56$	4
DST1	$5.78^{a}\pm1.24$	$5.11^{abc}\pm1.3$	$4.07^{bc}\pm1.63$	$4.91^{abc}\pm1.55$	5
DST3	$5.89^{a}\pm1.28$	$5.09^{abc}\pm1.44$	$4.53^{abc}\pm1.46$	$4.49^{bc}\pm1.49$	5
IRST1	$5.87^{a}\pm1.08$	$5.2^{ab}\pm1.47$	$4.71^{abc}\pm1.84$	$5.11^{ab}\pm1.73$	5
IRST3	$5.62^{a}\pm1.4$	$4.29^{bc}\pm1.53$	$4.02^{bc}\pm1.7$	$4.2^{bc}\pm1.6$	4

Key: Values are mean±standard deviations**.** The superscript letters along the column are mean separation sho (P<0.05); means in the same column with the same superscript letter are not significantly different. The scores are ba 1 and 7 as presented in section 5.2.3. RST1;RST3;MST1;MST3;RDST1;RDST3;MRST1;MRST-refers to the blendi Table 4.2

5.4 Conclusion.

Compositing of pre-gelatinized taro with soy flour significantly affects the intensity of sensory attributes of the developed snack bars. Compositing with roasted soy flour results in a snack bar with the highest colour intensity, highly perceivable aroma, least sugar intensity and less brittleness, while adding raw soy flour results in less colour intensity and highest beany flavour intensity. The PCA shows that as the level of complementation with soy flour increased, the first components that are negatively affected include surface gloss, sweet taste and fructurability while colour is the last to be affected. Despite the beany flavour, compositing with raw soy flour shows the highest overall acceptability with consumers as compared to the other snack bars. Owing to these sensory characteristics, soy flour can be used to complement other less protein-dense food such as taro.

CHAPTER SIX

MICROBIAL SAFETY AND PREDICTION SHELF LIFE OF PROTEIN-ICH SNACK BARS DEVELOPED FROM PRE-GELATINIZED TARO (*Colocasia esculenta*) AND SOYBEAN (*Glycine max* L.) COMPOSITE FLOUR USING ACCELERATED SHELF LIFE TEST (ASLT) BASED ON THE ARRHENIUS MODEL.

Abstract

Food safety and shelf stability are important characteristics of food. The objective of this research was to determine the microbial safety and predict the shelf life of protein-rich snack bars developed from pre-gelatinized taro and soybean composite flour using an accelerated shelf-life test (ASLT) based on the Arrhenius method. This was done by monitoring the rate of lipid oxidation using Thio-barbituric Acid Reactive Substances (TBARS) as a measure. The snack bars were stored at temperatures of 25°C, 35°C and 45°C for a period of 30days and analysis was done at 7days intervals. Temperature elevation is thought to speed up the deteriorative reaction. No coliforms, and S*taph aureus* growth were observed in the snack bars. It was observed that there was increased TBARS level with prolonged storage. Enriching taro with soybean also impacted significantly on the shelf life of the snack bars. From the results it was observed that the snack bars had a predicted shelf life of between 29 and 72 days. Use of food-grade antioxidants and antimicrobials can extend the shelf life of these snack bars.

6.1 Introduction.

In response to consumers' fast-paced lifestyles and growing demands for quick, shelf-stable, nutritious meals and high-quality meals and snacks, the food industry has been prompted to develop food that combines convenience and nutrition, such as snack bars (Ryavanki & Hemalatha, 2018). Snack bars typically contain cereals like oats, wheat, maize, rice, and tubers like sweet potatoes and cassava. Fortification of these snack bars with nutrient-rich ingredients such as legumes to enhance their nutritional, functional, and sensory properties are extensively documented. For example, Nurhusna *et al.* (2020) prepared a snack bar from sorghum and beans for pregnant women. Limsangouan *et al.* (2010) also looked at the nutritional value of extruded snacks made from cereals and legumes.

Fortification of snack bars with legumes that are protein-rich such as soybean flour, increases not just their protein quality but also their sensory qualities. Soybean also contains an appreciable amount of lipids (19% DM), with 57.74% polyunsaturated fatty acids (Hassan & Sherif, 2013). Pulungan *et al.* (2018) purport that rancidity is primarily the problem regarding foods with high-fat content. Rancidity can result from oxidation, enzyme action, and hydrolysis of the fat present in a food. Fat oxidation (oxidative rancidity) causes not only deterioration in the sensory qualities of the snack bars but also impacts shelf-life (Az *et al.*, 2022).

The consumer acceptance of a food product is a crucial factor in determining its shelf life. Shelf-life refers to duration a food item is considered suitable to consume or use when kept in the proper conditions (Haouet *et al.*, 2018). Also, following the current EU legislation, shelf life is known as the "date of minimal durability," and this applies to foods that are not highly perishable and do not pose an immediate threat to public health (Commission, 2005). Insufficient shelf life results in discontent or complaints from consumers. Such discontent not only affects the product's acceptance, sales and the brand's reputation but can additionally result in undernourishment and other serious health issues (Rasane *et al.*, 2015). This is sufficient justification for food developers to consider the shelf stability of their products.

Snack bars are typically dry and microbiologically stable due to their low moisture content. Both chemical and sensory changes can be taken into account when evaluating their stability in storage. Two distinct stability testing methodologies are commonly used to predict shelf life: real-time stability tests and accelerated stability studies (Haouet *et al.*, 2018). During accelerated stability testing, the product is subjected to intensified conditions of enhanced stress of the common accelerating factors, including temperature, humidity, moisture, and pH. For example, Corrigan *et al.* (2012) used temperature to model the shelf-life of fruit-filled snack bars, and Ryavanki and Hemalatha (2018) used humidity to accelerate the shelf-life of red sorghum flakes snack bars. The results from accelerated storage are then extrapolated using the Arrhenius equation to estimate the shelf life under normal storage conditions. Consequently, this study aimed at determining the microbial safety and predicting the shelf life of protein-rich snack bars formulated from pre-gelatinized taro and soybean composite flour using an accelerated shelf-life test (ASLT) based on the Arrhenius method.

6.2 Materials and Method

6.2.1 Materials

Pre-gelatinized taro flour was prepared as shown in section 4.2.2 and malted and roasted soybeans were prepared as par section 4.2.3. The blending of the different proportions soybeans with taro was done as per Table 4.1. Five snack bars were selected; RST, MST, RDST, MRST and RST3 were selected for shelf life study. This was done to test on the effect of compositing different soybean treatments and proportion of inclusion on the produced snack bars. Snack were prepared as shown in section 4.2.5

6.2.2 Microbial Analysis

Ten grams of the snack bar samples were weighed and mixed with 90ml sterile buffered peptone water and blended to form suspension. Serial dilutions of the suspension were done up to 10^{-3}. Enumeration of Total Viable Count (TCV) was done using Plate count agar (PCA), MacConkey Agar for Total Coliforms Count (TCC), Baid-Parker agar mixed with egg-yolk tellurite emulsion was used for *Staphylococcus aureus* and for Yeast and Molds counts, Potato Dextrose Agar (PDA) was used. All these were carried out following the pour plate technique (Doiphode & Mane, 2021). The analysis was done in three replications.

6.2.3 Predicting Shelf Life Using Arrhenius Model

The Accelerated Shelf-Life Testing (ASLT) method and the Arrhenius equation were used to estimate the shelf life as described by Pulungan *et al.* (2018). Snack bars packed in airtight zip lock bags were incubated at accelerated temperatures of 25°C, 35°C and 45°C. Three replications were used for observations, which were done every seven days for 30 days. The number of thio barbituric acid (TBA) was the metric tested. The linear regression model was determined by plotting the TBA value against the number of days of storage. To each 3 conditions of product storage temperatures, three equations were derived.

Three equations for the various storage temperatures (25°C, 35°C and 45°C) were generated using the data collected from TBA values of the snack bars and plotted against time (in days). The linear equation ($y = mx + c$) was obtained, where y depicts the characteristic value of Snack bars, c is the initial TBA value of the snack bar, m is the rate of TBA change, and x is the slope of storage period (in days). The value of the quality degradation rate (k) also known as the kinetic constant, was obtained from each linear regression equation (Gitalasa *et al.*, 2018; Jafari *et al.*, 2017).

To predict degrading behaviour, a graph of reaction kinetics for zero or first order was plotted from the storage slope (k), intercept (constant), and correlation coefficient (R^2). This was done by plotting natural log (ln) of k (*y-axis*) against 1/T (K^{-1}) (*x-axis*) and an Arrhenius equation was used to correlate the two. The value of the quality degradation rate (k) also known as the kinetic rate constant, was obtained from each linear regression equation: [$\ln k = \ln k_0^{-(Ea / R)(1/T)}$]Where: k is reaction rate constant, k_o is exponential factor E_a = activation energy, T is absolute temperature (K) and R is gas constant.

To estimate the shelf of the snack bars a mathematical model was used as described by Nicoli (2012). $SL = \frac{\text{TBA}lim - \text{TBA}t0}{kT}$, where TBA*lim* is the TBA corresponding to the acceptable limit of TBA set at 2.0mg/MDA) (Singh, Y. *et al.*, 2020) , TBA*t0* is the TBA value at zero storage time, and kT represents the constant at the selected storage temperature T.

6.2.4 Determination of Thio Barbituric Acid Reactive Substances in Snack Bars

Analysis of thio-barbituric acid reactive substance in the snack bars followed the protocol outlined by Zeb and Ullah (2016). Two grams of the sample was added into a 5ml test tube and 10ml of 100% glacial acetic acid was used as the solvent. 0.01% BHT (antioxidant) was added to prevent further oxidation of the mixture. The samples were then filtered after shaking for one hour. Following filtration the filtrate was then centrifuged and an extract for analysis was obtained. One ml extract of each sample was mixed with 1 ml thio-barbituric acid (TBA) reagent in a test tube and the mixture was heated for 1h in a boiling water bath at 95°C. The standard curve was generated using MDA (malondialdehyde tetrabutylammonium) salt solution and the total TBA reactive substance expressed in mg of MDA/kg sample. The absorbance was read at 532 nm using UV-visible spectrophotometer model PharmaSpec 1700 (Shimadzu, Japan) after cooling the test tubes at room temperature.

6.2.5 Statistical Analysis

Data obtained was analysed using the PROC GLM procedure of the Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.1. A test significance was done by performing an analysis of variance (ANOVA) at a 5% significance level. The means separation was done using Tukey's Honestly significant difference (HSD) method. The results are expressed as mean ± standard deviation from three replication measurements.

6.3 Results and Discussion

6.3.1 Effects of Enriching Pre-Gelatinized Taro with Soybean Flour on the Microbial Safety of the Snack Bars.

Table 6.1 summarizes the results for microbial count for the different snack bars samples. The results obtained for TPC ranged between 2.0 cfu/g – 4.0 cfu/g, Y/M from 0.00 cfu/g – 3.67 cfu/g and there was no growth for both *Staph. aureus* and TCC. Food safety is paramount in the pursuit of healthy eating and sustainable food systems as it assures that food is safe for human consumption. Microbial safety in ready to eat food product is of great importance so as to prevent incidences and occurrences of foodborne illness among the consumers. The data obtained in this study revealed that the results for the microbial counts in the different snack bars posed no health-threat as they were within the acceptable recommended limits for cereal-based baked products that is to say that the microbial counts must not exceed; total coliforms < 200 cfu/g, *Staph. aureus* < 10^2 cfu/g total viable count < 10^5 cfu/g, yeast and moulds < 10^4 cfu/g (Khanom *et al.*, 2016). No growth for TCC and *Staph. aureus* implied that good hygienic practices were observed while producing the snack bars since they normally find their way into food through faecal contamination of either the processing water, environment or handler. Following staining of the colony-forming units observed in yeast and mold growth, majority of the units were identified to fall under the taxa *Cladosporium spp., mucor* and *Saccharomyces spp.* These are generally food spoilage fungi and as such impact on the shelf-stability of product.

Table 6.1 Microbial Count for Snack Bar made from Soy-Enriched Pre-gelatinized Taro Flour

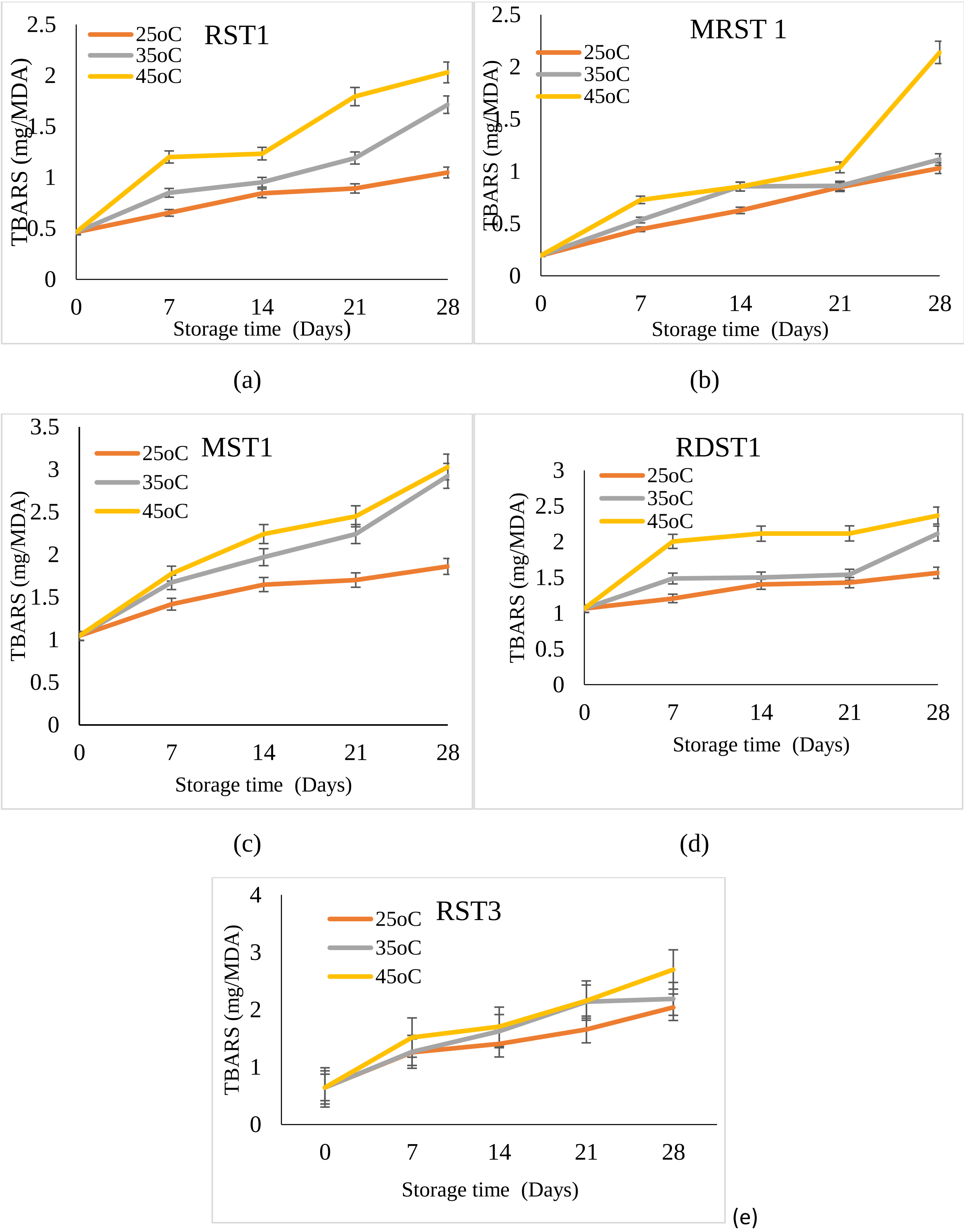
Sample	TCC	*Staphylococcus aureus*	TPC	Y/M
RST1	**NG**	**NG**	$3.33^{a} \pm 0.67$	$2^{ab} \pm 0.58$
RST2	**NG**	**NG**	$2^{a} \pm 0.58$	$1^{ab} \pm 0.58$
RST3	**NG**	**NG**	$3^{a} \pm 0.58$	$1.67^{ab} \pm 0.33$
RST4	**NG**	**NG**	$2.33^{a} \pm .033$	0^{b}
MST1	**NG**	**NG**	$2^{a} \pm 0.58$	$3^{ab} \pm 0.58$
MST2	**NG**	**NG**	$2.33^{a} \pm 0.88$	$3^{ab} \pm 0.58$
MST3	**NG**	**NG**	$3^{a} \pm 0.58$	$2.67^{ab} \pm 0.88$
MST4	**NG**	**NG**	$2.67^{a} \pm 0.88$	$3.33^{a} \pm 0.88$
RDST1	**NG**	**NG**	$2.33^{a} \pm 0.88$	$1^{ab} \pm 0.00$
RDST2	**NG**	**NG**	$3^{a} \pm 0.58$	$1.33^{ab} \pm 0.33$
RDST3	**NG**	**NG**	$3.33^{a} \pm 0.33$	$2^{ab} \pm 0.58$
RDST4	**NG**	**NG**	$2.67^{a} \pm 0.33$	$1.67^{ab} \pm 0.33$
MRST1	**NG**	**NG**	$2.67^{a} \pm 0.67$	$3.67^{a} \pm 0.33$
MRST2	**NG**	**NG**	$3.12^{a} \pm 0.68$	$3^{ab} \pm 0.58$
MRST3	**NG**	**NG**	$4^{a} \pm 0.58$	$1^{ab} \pm 0.58$
MRST4	**NG**	**NG**	$3^{a} \pm 0.58$	$3.33^{a} \pm 1.2$

Key: Values are mean±standard deviations**.** The superscript letters along the column are mean separation showing significant difference at (P<0.05); means in the same column with the same superscript letter are not significantly different. NG-No Growth. TCC-Total Coliform Count, TPC- Total Plate Count, Y/M- Yeast & molds

RST1;RST2;RST3;RST4;MST1;MST2;MST3;MST4;RDST1;RDST2;RDST3;RDST4;MRST1;MRST2;MRST3;MRST4-refers to the blending proportions as shown in Table 4.1.

6.3.2 Effect of Enrich Taro with Soybean Flour on the Thiobarbituric Acid Reactive Substances (TBARS) in the Snack bars during Accelerated Shelf Life Testing.

Changes in the TBARS content is illustrated in the Figure 6.1. Overall, the proportion of TBARS increased progressively over time during storage period and across the different temperatures. Deterioration of fat-containing foods is primarily attributed to lipid oxidation resulting in the formation of tasteless and odourless hydroperoxides. Further breakdown of these hydroperoxides results in flavourful secondary oxidation products, primarily aldehydes like malondialdehyde (MDA). Papastergiadis *et al.* (2012) describes MDA as a 3-carbon dialdehyde that is mutagenic to humans as it able to form adducts with DNA and proteins. MDA and other products formed during lipid peroxidation also react with thio-barbituric acid to produce a red pigment that can be detected colorimetrically as such referred to as Thio-Burbituric Acid Reactive Substances (TBARS) (Dorsey & Jones, 2017). TBARS can serve as a reliable index of early stages rancidity (Irwin & Hedges, 2004). When stored at accelerated temperatures 25°C, 35°C and 45°C there was a proportionate increase in the TBARS in the snack bars by day 28 as follows. In RST3 the levels of TBARS increased by 218.75%, 242.18% and 321.88% respectively; in MRST1 by 442.11%, 484.21% and 1026.32%; in MST1 by 77.14%, 178.1% and 188.57%; in RDST1 by 48.11%, 100%, and 123.58% while in RST1 TBARS increased by 128.26%, 271.74% and 341.30% respectively. MRST had the highest change in TBARS levels when stored at 25°C varying between 0.19±0.02 and 1.03±0.04 mg/MDA while RDST had the least change varying between 1.06±0.02 and 1.57±0.1 mg/MDA and as expected the change in proportion of TBARS in the snack bars were more pronounced at 45°C this is because at elevated temperatures, rate of chemical reactions is increased, which implies product quality will decline rapidly. Several researchers have also used TBARS assay to monitor changes in the lipid content of their products. For instance, Padmashree *et al.* (2012) noted change of 0.19 to 0.41 mg/MDA in TBARS of protein-rich cereal bars stored for 9 months and Nurhayati *et al.* (2017) used it as a parameter to forecast the long-life of canned gudeg stored at 37 and 50.



Key:TBARS-Thiobarbituric acid Reactive Substances;MDA-Malondialdehyde tetrabutylammonium; RST1;RST3;MST1;RDST1;MRST1-refers to the blending proportions as shown in Table 4.1.

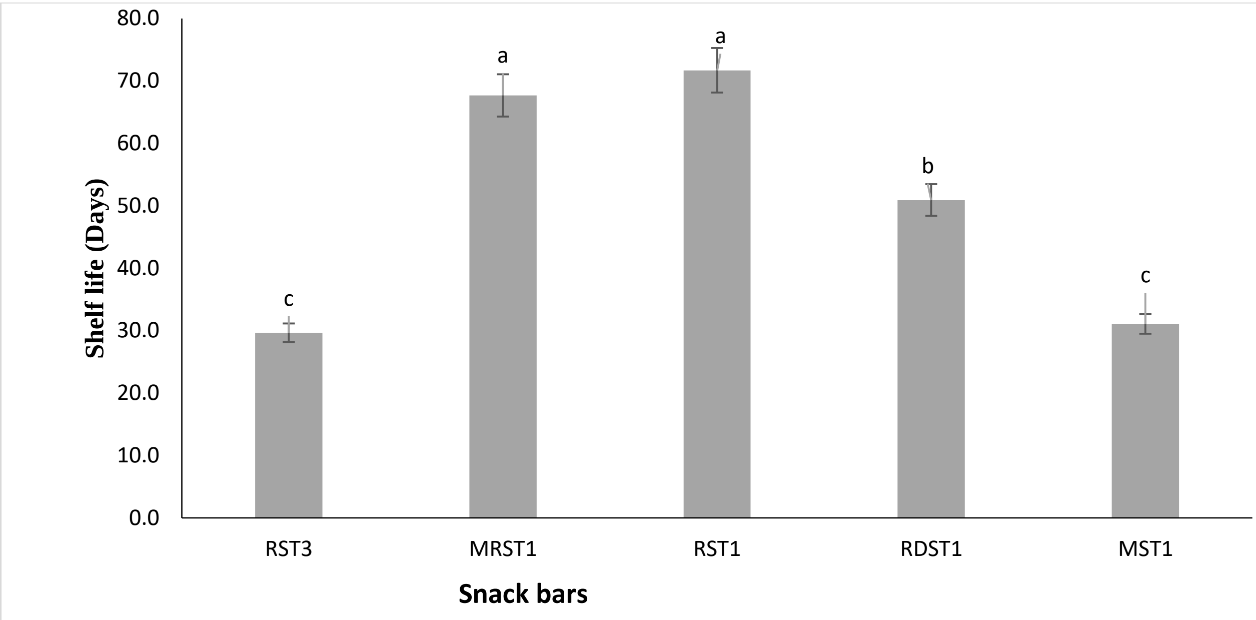
Figure 6.1: Changes in TBARS Levels in the Snack Bars during Storage at Different Temperatures

6.3.3 Effect of Enriching Taro with Soybean Flour on Predicted Shelf Life of the Snack Bars.

Arrhenius model is a simulation model to evaluate rate of quality decline of product. This technique quantifies impact of temperature on degradation values and predict storage life using linear regression (Az *et al.*, 2022). In this study it is assumed that rancidity is the primary cause of degradation measured by the level of TBARS in the soy-enrich snack bars. Predicted shelf life of the snack bars stored at 25°C based on the change in proportion of TBARS using Arrhenius Equation is shown in Table 6.2 and illustrated in Figure 6.2. Shelf life of the snack bars was observed to vary between 29 and 72 days. Addition of raw, malted, roasted and malted-roasted soy at 10% resulted in a predicted shelf life of 72, 31, 51 and 68 days, respectively, when the bars are stored at 25°C. This can be traced back to the high crude fat level mention in subsection 4.3.1 which make the snack bars susceptible to rancidity. Increasing the level of soy complementation to 30% resulted is a decrease of predicted shelf-life by 100.4% from 72 to 29 days as observed with addition of raw soy in RST snack bar samples. This is because more substrate for oxidation to occur has been provided. This is backed up by a study conducted by Nazaruddin (2017) who discovered that the duration of storage and oxidative stability of biscuits containing oil from soybeans deteriorated as the amount of soybean oil in them increased. This prediction of shelf life can aid in the development of preventative strategies against lipid oxidation-induced deterioration. The observations made in this study agree with the results obtained by Wahyuni (2018) who observed that spirulina-based biscuits could be stored up to 52 days at 35°C and Afifah *et al.* (2022) who noted that sagon processed from *lindur (Bruguiera gymnorrhiza* L.*)* and soy flour had a shelf life of 37 days when stored at 25°C. As suggested by Wahyuni (2018) various food-grade antioxidants and antimicrobials may be used to enhance the resilience of food commodities against physical, chemical, and biological deterioration.

Table 6.2: Arrhenius Equation and the Predicted Shelf- life of Soy-Enriched Snack Bars

Sample	Arrhenius Equation	Coefficient of Determination (R^2)	Shelf Life in Days
RST1	-4641.2x +11.732	0.9476	72
RST3	-1887.5x + 3.2492	0.991	29
MST1	-4223.5x +10.691	0.8238	31
RDST1	-3788.5x +8.7171	0.9525	51
MRST1	-3314.9x +7.5	0.7801	68



Key: Values are mean±standard deviations**.** The superscript letters along the bars are mean separation showing significant difference at ($P<0.05$); bars with the same letter are not significantly different. RST1; RST3; MST1; RDST1 MRST1 -refers to the blending proportions as shown in Table 4.2.

Figure 6.2: Predicted Shelf-life of Soy-Enriched Snack Bars

6.4 Conclusion.

Microbial safety of food is of great importance in order to reduce occurrences of foodborne illness and food spoilage. The TBARS level increase generally over time when stored at different temperatures, implying that lipid oxidation is also accelerated as the temperatures increased. Arrhenius model of the ASLT is used to predict the shelf life of snack bars made from taro flour enriched with soybeans. Snack bars made by compositing raw soy at 10% with pre-gelatinized taro flour have the longest predicted shelf-life of 72 days. Use of food-grade antioxidants and antimicrobials is recommended to extend the shelf life of these snack bars.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 General Discussion

7.1.1 Study Rationale

Under nutrition, especially Protein Energy Undernutrition (PEU), is a public health issue since it increases the risk of morbidity and mortality. It is also an obstacle underscoring the immense challenge of realizing the second sustainable development goal (SDG) of the Agenda 2030 which seeks to eradicate hunger, achieve food security and improve nutrition in poor and middle-income countries (SDG, 2018). PEU is prevalent globally, affecting both children and adults in low-income nations. According to the Kenya Demographic Health Survey 2014, one in every 4 children suffers from chronic under-nutrition. (Demographic, 2014). Exploiting locally available underutilized food crops to improve staple foods has been established as a strategy for attaining food and nutrition security in several regions. Nations with growing economies grappling with the threat of food insecurity and malnutrition have been recommended to adopt this strategy as it ensures sustained food supply and affordability in addition to enhancing the nutritional value of mainstay foods (Wafula, 2021). Taro, for instance, is rich in carbohydrates and other micronutrients but low in proteins (Rashmi *et al.*, 2018). However, compared to other legumes, soybeans are excellent source of quality proteins (Farzana *et al.*, 2017). Increased consumption of these ingredients may boost their usage, thereby enhancing nutritional status, food, and income for households.

Food material science seeks to understand the composition and behaviour of diverse materials used as food or as ingredients in food compositions. This discipline is gaining prominence among scientists designing novel food products to satisfy consumer wants. Incorporating food processing technology with food enrichment can increase nutrition and provide value to food. When food is pre-gelatinized, its biochemical and conformational properties are altered. Recent research trends have shown increased use of pre-gelatinized starch as a versatile and multifunctional pharmaceutical and industrial excipient. This is due to its suitable physicochemical properties and relative inertness (Lestari *et al.*, 2019; Liu *et al.*, 2017).

Thus, this research envisaged prospects of enriching pre-gelatinized taro with soybeans and developing protein-rich snack bars that can provide an excellent avenue for delivering the required nutrient to enhance nutrition.

7.1.2. Critical Analysis of the Methodology

Four major research hypotheses are tested throughout the thesis: (i) Pre-gelatinization conditions have no significant effect on the physicochemical properties of taro flour. (ii) Enrichment of pre-gelatinized taro flour with soybeans has no significant effect on the microbial and nutritional properties of the developed snack bar. (iii) Enrichment of pre-gelatinized taro flour with soybeans has no significant effect on the sensory properties of the developed snack bar. (iv) Enrichment of pre-gelatinized taro flour with soybeans has no significant effect on the shelf life of the developed snack bar. Chapters 3, 4, 5, and 6 present the findings that test these hypotheses. Therefore, the scientific methods employed to investigate these hypotheses are highlighted in this chapter and it discusses the important findings from Chapters 3, 4, 5, and 6 and their significance for physico-chemical, microbial safety, nutritional, and sensory and shelf-life parameters.

This study employed a two-step methodology. The first step was to develop pre-gelatinized flour from taro composite blends with the study and investigate how the pre-gelatinization conditions affected the total oxalates and techno-functional properties of the resultant flours. The method that gave the least total oxalate content and improved techno-functional properties was chosen for use in subsequent analysis. The second phase was to assess how the enriching pre-gelatinized taro flour with soybean (with different treatments) impacted the microbial safety, nutritional, sensory, and shelf life characteristics of the developed snack bars.

Analysis of Variance (ANOVA) was performed to determine whether or not the primary factors had any discernible effect and whether or not there was any interaction between them. A completely randomized design in a factorial experimental arrangement of the two ingredients was employed for chapters 3, 4, 5 and 6 to assess the effect of individual methods or ingredient variables and their impact due to their interaction with the response variables. Chapter three main focus was on quantifying the change in the physic-chemical components of taro flour due to the pre-gelatinization method. Hot extraction and HPLC methods were used to determine the total oxalate content of pre-gelatinized taro flour. In their studies comparing the different and most ideal methods of oxalate extraction from plant tissues, researchers such as Hönow and Hesse (2002) and Al-Wahsh *et al.* (2012) hypothesised that hot extraction ensures a high yield of total oxalates extraction over cold extraction (which could result in inadvertently low values due to incomplete extraction). However, hot extraction can result in oxaloneogenesis due to in vitro synthesis of oxalates from oxalate precursors and source-substances like ascorbate and carbohydrate, a limitation that the study did not account for.

Chapter four was centred on quantifying the alterations in the nutritional components of the developed snack bars attributed to the ingredient variables used. Apparent *invitro* protein digestibility was determined using the multi-enzyme assay as a proxy for *invivo* measures (gastrointestinal tract simulation) of digestion. The endogenous losses are not, however, simulated by this technique. Witten and Aulrich (2022) found that the in-vitro assay could not provide accurate prediction of the amino acid and crude protein digestibility in their study. This is because the digestibility of arginine, histidine, and tyrosine, unlike that of other amino acids, could not be reliably determined using the crude protein digestion. Chapter five focused on determining how the ingredient variables used to develop the snack bars affected their sensory characteristics. Chapter six looked to assess the impact the ingredient variables had on microbial safety and predicted the shelf life of the snack bars using the Arrhenius model and quantifying the Thio-barbituric Acid Reactive Substance (TBARS) as the indicator for the extent of lipid oxidation. Compared to the peroxides whose formation is low at first during the induction period, TBARS generally show a steady increase as a sample becomes more rancid (Gheisari, 2011). It is relatively simple and has a short assay time however, just like peroxide value a low TBARS score may indicate that either volatile aldehydes were lost during processing and storage of the lipid or aldehydes that have not yet been generated. Because of the artificial formation of MDA and other aldehydes, as well as a number of non-peroxidation compounds, such as soluble proteins, peptides, and pigments in food samples, the TBARS value derived from the color reaction shouldn't be implied to indicate the absolute level of peroxidation (Song & Shurson, 2013).

7.1.3 Effects of Compositing Pre-gelatinized taro Flour with Soybeans on the Quality Parameters of the Developed Snack Bars

The pre-gelatinization processes greatly reduced the overall oxalate content of taro flour while also significantly improving its physico-chemical properties. The goal here was to find a method that significantly reduces the oxalates in taro, which are detrimental to their use. The boiling method (at 95 °C for 30 min.) seems to be a practically feasible approach because the proportion of the flour's total oxalate content was reduced by the highest percentage using this method. The flour's bulk density of 0.85 also made it suitable for use in designing a snack bar that can be consumed by both children and adults. Following that, soybean flour that had undergone several processing steps, including raw, malting, roasting, and malting-roasting was blended with the pre-gelatinized flour. Increased nutritious components including lipids and proteins, enhanced protein digestibility, increased total phenolic content, and decreased lead and cadmium levels were all significantly influenced by these complementation. These variations resulted from Maillard and caramelization-type biochemical interactions within and between the nutritional components. Enzyme kinetics explained the improved *in-vitro* protein digestibility, while hydrophilic bonding and leaching accounted for the low levels of heavy metals. By incorporating soybean flour to pre-gelatinized taro, the intensity of the sensory qualities, including colour, aroma, taste, texture, flavour, and aftertaste, was also significantly affected. Colour was the last component to noticeably change according to Principal Component Analysis (PCA), which additionally showed the order in which the attributes were influenced. The processing environment and handling procedures have a considerable impact on preventing or reducing microbiological contamination, ensuring food safety, and extending duration of the shelf life of snack bars. The snack bars' microbiological count was acceptable and did not endanger the health of the consumer. On the other hand, staining of the colony-forming units seen in yeast and mould growth revealed that the majority of the units belonged to the taxa *Saccharomyces spp., Cladosporium spp.,* and *mucor*, which are often food spoilage fungi and impact the stability of the snack bars' shelf-life. By employing markers associated with degradative reactions, prediction of shelf life based on fingerprinting of reaction kinetics has been improved to generate more precise shelf life estimates. The rationale underpinning Arrhenius in accelerated shelf life testing is that high temperatures can hasten the rate of reaction especially during storage. When the snack bars were stored at 25°C increasing the level of soy complementation to 30% resulted in a 100.4% decrease in estimated shelf-life from 72 to 29 days thus necessitating the need to add anti-oxidants into the bars to prolong their self-life.

This study gives valuable insights into developing novel foods, particularly nutrient-dense convenient foods made from pre-gelatinized taro and soybeans. The formulation in itself enriches taro with nutrients from soybeans, and thus producing snack bars from the blend provides a convenient avenue for delivering the nutrients. Besides the snack bars, the blends of flour made from compositing pre-gelatinized taro and soybean could be used in various domestic and industrial applications.

7.2 Conclusions

i. The different pre-gelatinization conditions has significantly reduce the total oxalate content and improved the techno-functional properties of taro flour compared to the native flour.

ii. Enriching pre-gelatinized taro with soybean flour significantly increases all the nutritional indices, especially those relating to protein, lipids, and gross energy and *invitro*-protein digestibility.
iii. Enriching pre-gelatinized taro with soybean flour significantly affects the intensity of sensory attributes and the consumer acceptance of the developed snack bars. Adding roasted soybean flour greatly intensifies the colour intensity and perceivable aroma.
iv. Enriching pre-gelatinized taro flour with soybeans significantly affects the shelf-of the developed snack bars for example snack bars made by compositing raw soy at 10% with pre-gelatinized taro flour has the longest predicted shelf-life of 72 days.

7.3 Recommendations

The following recommendations are appropriate in light of the outcomes of my research.

i. Owing to the increased physico-chemical properties and reduced oxalate content, the suitability of pre-gelatinized taro flour should be determined for application in various food products such as thickening agent, formulation of complementary and bakery food products.
ii. Pre-gelatinization and baking can be used as methods to reduce the Lead and Cadmium present in a food
iii. Enrichment with soybean is best done up to 30%.
iv. The snack bars should be determined for use as a supplementary and emergency food products however they should incorporated with fiber–rich ingredients to boost the dietary fiber content.
v. Owing to the sensory characteristics and general consumer acceptability, soy flour should be used to complement other less protein-dense food such as taro.
vi. Food-grade antioxidants and antimicrobials should be used to extend the shelf life of these snack bars.

5.3 Areas for Further Research

i. Follow-up studies using *in vivo* animal models and human intervention studies using taro composited with soybean flour snack bars is required to support these findings.
ii. Studies on the amino acid profile of the snack bars are necessary.
iii. Comparison study for the taro-soybean blend snack bars against PEM products in the market is necessary to evaluate it potential as an alternative nutritional intervention.

iv. Real-time shelf life study should be carried out to validate the results obtained from accelerated shelf-life testing.

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APPENDICES

Appendix I: Selected Statistical Outputs

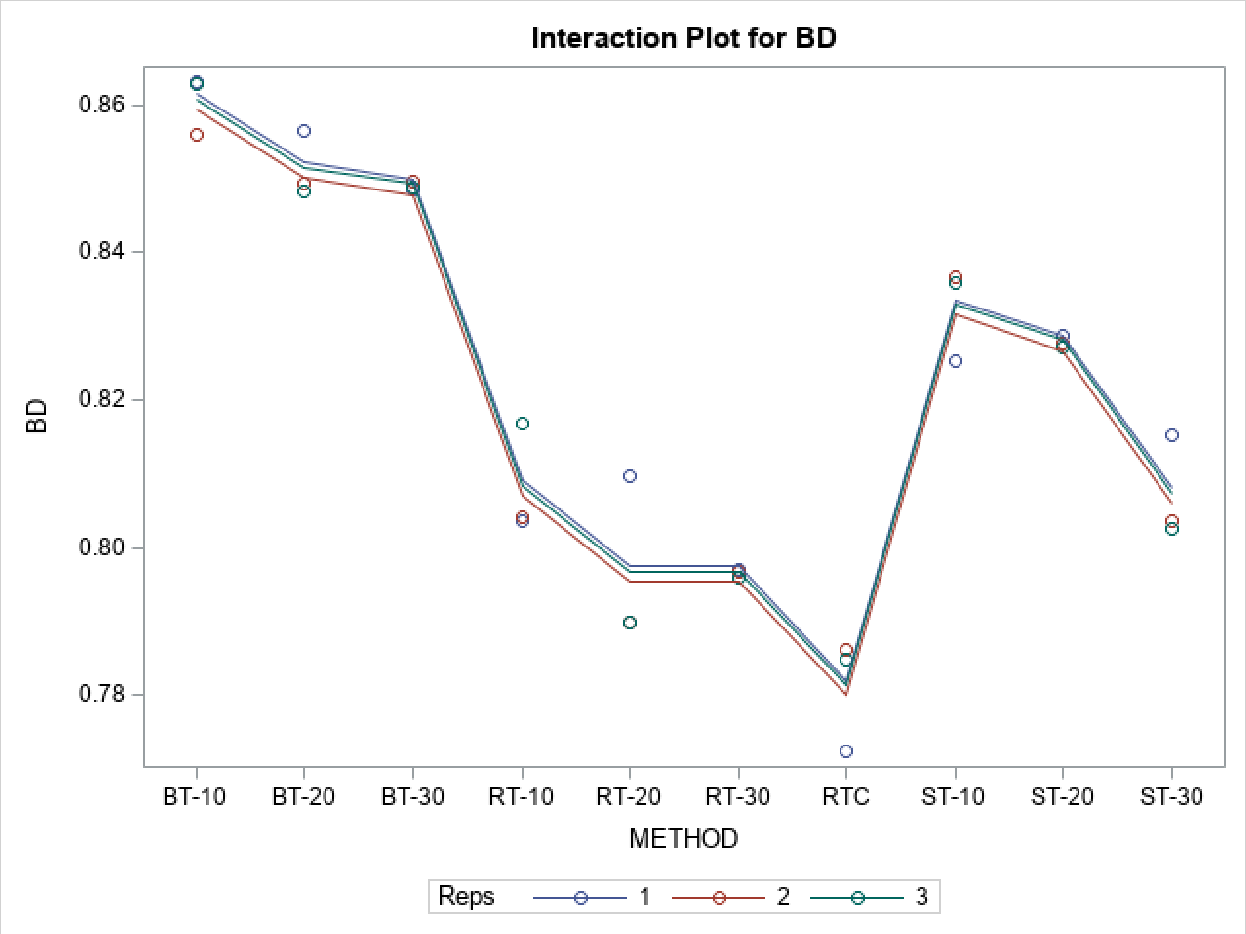


Fig. 1: Interaction plot for bulk density of pre-gelatinized taro flour as influenced by the Pre-gelatinization conditions.

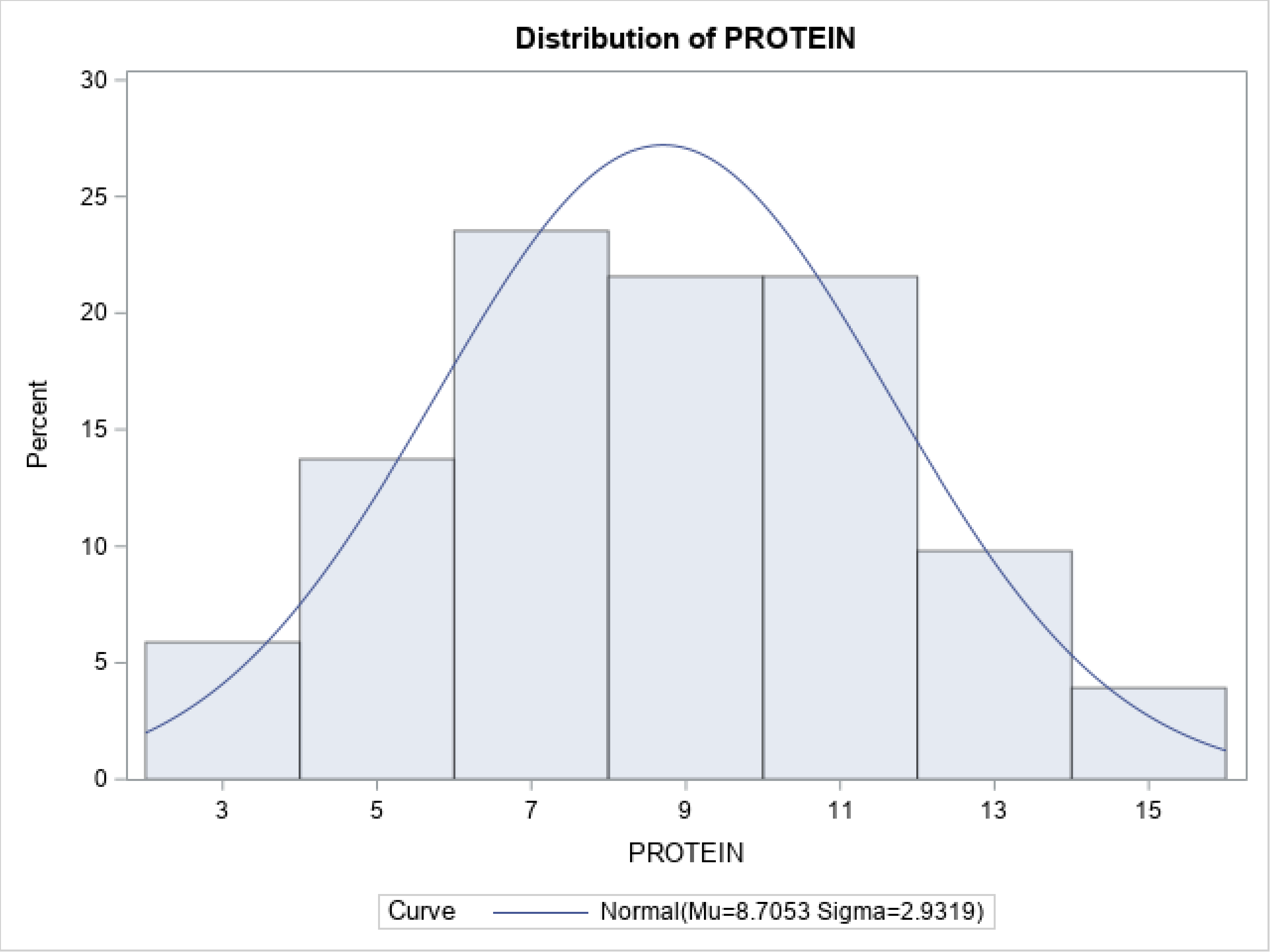


Fig. 2: Distribution Histogram of protein content of Soy-enriched Snack Bars.

Appendix II: Sensory Evaluation Score Sheets

SCORE SHEETS FOR QUANTITATIVE DESCRIPTIVE SENSORY ANALYSIS AND CONSUMER ACCEPTANCE OF THE SNACK BAR.

Panellist number ……………………………………………………………

Date ………………………………………………………………………….

Gender: ……………………………………… **Age Group……………….…………**

Instructions:

You are provided with 13 coded samples of snack bars. You are required to rate each of the snack bar as per the threshold of the attributes listed on top of the table in the appropriate box base on a 9-point hedonic scale.

Note:

- **Please rinse your mouth before starting and also in between when evaluating the samples.**
- **Evaluate the snack bar in front of you by looking at it, feeling it and tasting it.**
- **Assign an appropriate score (with 1 being the least and 9 being the very) for each of the listed parameters/components.**

Snack Bar specific evaluation

APPEARANCE

Colour: Degree of Brownness

Sample Code	1	2	3	4	5	6	7	8	9
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MBA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TXR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
IRM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RSA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SYR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
CAM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ZRT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RYT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ERM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TZC	[ ] Light	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ] Dark

Consistency: Degree of visual uniformity of the sample/level of smoothness

Sample Code	1	2	3	4	5	6	7	8	9
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MBA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TXR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
IRM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RSA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SYR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
CAM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ZRT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RYT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ERM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TZC	[ ] **Least Smooth**	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ] **Very Smooth**

Degree of compactness of the cross-section

Sample Code	1	2	3	4	5	6	7	8	9
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MBA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TXR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
IRM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RSA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SYR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
CAM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ZRT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RYT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ERM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TZC	[ ] **Least Compact**	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ] **Very Compact**

Surface appearance: Degree of glossiness

Sample Code	1	2	3	4	5	6	7	8	9
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Dull**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Glossy**

FLAVOUR

Aroma: aroma associated with baked products.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least Intense**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Very Intense**

Caramel: flavour associated with caramelization.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least Intense**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Very Intense**

Sugary: Degree of sweetness associated with baking sugar.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least Intense**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Very Intense**

Astringency: causes puckering/shrinking of the tongue surface.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

TZC	**[ ] Least Intense**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ] Very Intense**

Starchy: associated with high starch foods.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ] Least Starchy**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ] Very Starchy**

Beany Flavour: flavour associated with uncooked beans.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ] Least Intense**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ] Very Intense**

Aftertaste: how long the after-taste lasts/lingers in the mouth.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least Intense**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Very Intense**

TEXTURE

Dryness: amount of saliva required when chewing

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least Dry**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Very Dry**

Cohesiveness: how particles tend to agglomerate/stay together during chewing

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	Least Cohesive								**Very Cohesive**

Fructurability: the force with which the sample raptures

Sample Code	1	2	3	4	5	6	7	8	9
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MBA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TXR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
IRM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RSA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SYR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
CAM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ZRT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RYT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ERM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TZC	[ ] Least Brittle	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ] Very Brittle

Grittiness: Amount of small, hard particles between teeth during chew

Sample Code	1	2	3	4	5	6	7	8	9
RXS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MBA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TXR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
IRM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AMR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RSA	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SYR	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
CAM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ZRT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RYT	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ERM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
TZC	[ ] Least	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ] Many

Particles: quantity of particles left in the mouth

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Many**

Stickiness: degree to which residues stick to the teeth.

Sample Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RXS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
MBA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TXR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
IRM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
AMR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RSA	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
SYR	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CAM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ZRT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
RYT	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
ERM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
TZC	**[ ]** **Least Sticky**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]** **Very Sticky**

Comment:

Score Sheet for Consumer Acceptance Sensory Analysis

Panellist code…………………………… Name of Panellist…………………………….

Date…………………….

Instructions:

You are provided with 8 coded samples. You are required to score and record each sample as per your judgement of the attributes listed on the left side of the table in the appropriate box. You can score 7 = like extremely, 6 = like moderately, 5 = like slightly, 4 = neither like nor dislike, 3 = dislike slightly, 2 = dislike moderately, 1= dislike extremely.

Attribute	**Sensory Scale**	**Sample Codes**							
		RSA	**SYR**	**CAM**	**ZRT**	**RYT**	**ERM**	**TZC**	**TXR**
Colour	(7= Like extremely to 1= Dislike extremely)								
Flavour	(7= Like extremely to 1= Dislike extremely)								
Texture	(7= Like extremely to 1= Dislike extremely)								
Taste	(7= Like extremely to 1= Dislike extremely)								
General Acceptability	(7= Like extremely to 1= Dislike extremely)								
Comments (if any)									

Sensory Panel Recruitment Form

I………………………………………………… have voluntarily agreed to take part in this study. I understand that I will not directly benefit from this study. I have had the study explained to me and I understand that it entails sensory evaluation of Snack bars. My participation in this study involves tasting of the snack bar and profiling the predetermined sensory properties according to my perception against the standards. I confirm that I am not allergic to product and do not have any issue consuming any of the ingredients contained in food product. I understand that the results will be kept for 3 months after the date of examination and will be treated confidentially. My identity will remain anonymous after the study and this will be done by coding my details.

………………………. ……………………………

Signature of participant Date

…………………………

Signature of researcher

I believe that the participant is giving informed consent to participate in this study.

Appendix III: NACOSTI Research Authorization

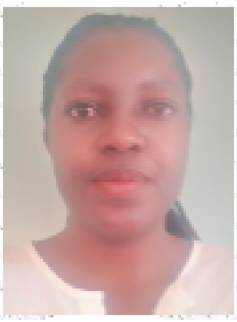
REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 253360

Date of Issue: 25/February/2022

RESEARCH LICENSE



This is to Certify that Miss.. Irene Ragar Oyim of Egerton University, has been licensed to conduct research in Nakuru on the topic: EVALUATION OF QUALITY PROPERTIES OF PROTEIN-RICH SNACK BAR DEVELOPED FROM PRE-GELATINIZED TARO (Colocasia Esculenta L.) FLOUR ENRICHED WITH SOYBEANS (Glycine Max L.). for the period ending : 25/February/2023.

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Appendix IV: Ethical Clearance

EGERTON **UNIVERSITY**

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EGERTON UNIVERSITY RESEARCH ETHICS COMMITTEE

EU/RE/DVC/009
Approval No. EUREC/APP/144/2021 **10th November, 2021**

Irene Ragar Oyim
P.O. Box 536-20115
Egerton
Telephone: +254711936547, +254789595195
E-mail: ireneoyim@gmail.com

Dear Irene,

RE: ETHICAL APPROVAL: EVALUATION OF QUALITY PROPERTIES OF PROTEIN RICH SNACK BARS DEVELOPED FROM PRE-GELATINISED TARA FLOUR ENRICHED WITH SOYA BEANS

This is to inform you that ***Egerton University Research Ethics Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUREC/APP/144/2021.*** The approval period is ***10th November, 2021 –11th November, 2022.***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Research Ethics Committee***.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Research Ethics Committee*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Egerton University Research Ethics Committee*** within 72 hours
v. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.

"Transforming Lives through Quality Education"

Appendix V: Publication

Food and Nutrition Sciences, 2022, 13, 511-525
https://www.scirp.org/journal/fns
ISSN Online: 2157-9458
ISSN Print: 2157-944X

Effect of Pre-Gelatinization Conditions on the Total Oxalate Content and Techno-Functional Properties of Taro (*Colocasia esculenta*) Flour

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https://doi.org/10.4236/fns.2022.136039

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Abstract

Like most roots and tubers, taro (*Colocasia esculenta*) corms have a short shelf-life due to the high moisture content, which aggravates their post-harvest losses. They also contain high amounts of calcium oxalates, limiting their use in food applications. To help add value and diversify the use of taro corms as well as curb food losses, various strategies have been proposed, such processing of the corms into flour. This study aimed at evaluating the total oxalate content and techno-functional properties of taro flour as affected by the pre-gelatinization conditions (*i.e.*, method and time). Pre-gelatinized taro flour was prepared by subjecting peeled and cleaned taro corms to roasting (190˚C), boiling (100˚C), and steaming (100˚C) for 10 min, 20 min and 30 min, respectively, for each method, followed by drying at 55˚C and milling. Generally, all the properties of flour were significantly affected by the pre-gelatinization conditions ($P < 0.05$). The total oxalate content of the pre-gelatinized taro flour ranged from 33.26 to 76.90 mg/100g. Pre-gelatinization by boiling significantly reduced the oxalate content (56.7%), while roasting resulted in the least reduction (36.2%). The flour colour *i.e.* L^*, hue, and chroma ranged from 38.47˚ - 70.30˚, 42.64˚ - 69.43˚, and 7.78˚ - 10.58˚, respectively. Roasting resulted in flour with the largest L^* (70.30˚) and hue angle (69.43˚). Boiling also resulted in flour with the highest bulk density (BD) (0.86 g/cm³) and the lowest water solubility index (WSI) (9.39%). Steamed flour had the highest water absorption index (WAI) (3.81 g/g), water holding capacity (WHC) (4.59 g/g), and swelling capacity (SC) (4.86 g/g). This study shows that pre-gelatinization (*i.e.* by boiling, steaming or roasting) significantly affects the total oxalate content and techno-functional properties of taro flour, which in turn influences its use in other food applications thus increasing the utilization and production of taro simultaneously.

Appendix VI: Conference Presentation

EVALUATION OF THE EFFECT OF PREGELATION CONDITIONS ON THE PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF TARO (Colocasia esculenta) FLOUR.

Irene oyim

Egerton University

Keywords: Food insecurity, Taro, Flour, Pre-gelatinization.

Published

01-04-2022

Abstract

Under the threat of food insecurity, various strategies have been implemented to help curb food losses and diversify utilization of under-produced, underutilized and underexplored food ingredients through value addition. Like most roots and tubers, Taro (*Colocasia esculenta*) corms have a short shelf life due to the high moisture content. They also contain high amounts of calcium oxalates which limit their use in food applications. This study aimed at evaluating the physico-chemical and functional properties of taro flour as affected by the pre-gelatinization conditions (i.e., method and time). Pre-gelatinized taro flour was prepared by subjecting peeled and cleaned taro corms to roasting (190°C), boiling (100°C), and steaming (100°C) for 10mins, 20mins and 30mins respectively. Generally, all the

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How to Cite

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