

**DEVELOPMENT AND CHARACTERIZATION OF PRODUCTS FROM
SELECTED VARIETIES OF SWEET POTATOES (*Ipomoea batatas L.*) IN
UGANDA**

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DECLARATION

I, **Catherine Acio** hereby declare that the work presented herein is original and has never been submitted to any University or Institution of Higher Learning for any academic award.

Signature..... **Date**.....

APPROVAL

This is to certify that Ms. Acio Catherine conducted a study titled “Development and characterization of products from selected varieties of sweet potatoes” under our supervision. We approve the submission of this dissertation.

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DEDICATION

This dissertation is dedicated to my children, Mariana, Matteo, Maceo and Mariella and I pray that they grow up blessed in all their undertakings. And in a special way to my parents, siblings and Leonard who kept me challenged to get this work into completion.

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ABSTRACT

This research aimed to develop and characterize sweet potato products from selected varieties from Uganda as a potential raw resource for the food processing sector. The selected local varieties included *Sukali*, *New Kawogo*, *Mubalila Bbali*, *Njule*, *Nakakande*, and *Kasanda* and the hybrid varieties included Narospot 1, Naspot 12, Naspot 8, and Naspot 13. The sweet potato varieties (both local and hybrid) were sourced from a multiplication farmer at Bombo, Luweero district and brought to the laboratory for analysis. The varieties were characterized for their vitamin A content, total polyphenols, starch, protein, fiber, ash, carbohydrate and dry matter content. The starch extracted from the sweet potatoes was also characterized. Sweet potato products, including bread, cakes, cookies, instant porridge and meal powder were developed using Naspot 13 and *Kasanda*. The instant porridge and meal were made by incorporating sweet potato flour with silverfish, egg, and milk powders, followed by extrusion cooking and milling. These products were evaluated for texture, rheological properties, and other nutritional attributes. The selected local and hybrid sweet potato varieties exhibited significant variation in both skin and pulp color. The dry matter content ranged between 29.5% in *Nakakande* and 42.8% in *New Kawogo*. Beta-carotene content varied between 6.48 µg/g in *Sukali* and 65.56 µg/g in *Njule*. Polyphenol content ranged between 0.178% and 0.554%, in Naspot 8 and *Kasanda* respectively. pH values ranged between 6.42 and 7.60 in *Kasanda* and *Nakakande* respectively. Crude ash content varied between 0.25% and 1.67%, with *Nakakande* and Naspot 13 having the lowest and highest values. Crude fat content ranged between 1.67% and 5.50%, with Narospot 1 and Naspot 12 having the lowest and highest values. Crude fiber content ranged between 2.22% and 4.50%, with *Mubalila Bbali* and Naspot 8 having the lowest and highest values. Protein content ranged between 1.79% and 4.77%, with *Mubalila Bbali* and Naspot 8 having the lowest and highest values. Moisture content ranged between 57.2% and 70.5%, with *New Kawogo* and *Nakakande* having the lowest and highest values. Total carbohydrate content ranged between 21.8% and 32.2%, with *Njule* and *New Kawogo* having the lowest and highest values. Regarding the physicochemical characteristics of the extracted starch, its water holding capacity ranged between 0.81 g/g and 1.20 g/g; Peak viscosity ranged between 10834 cP and 14399 cP; trough viscosity between 1081 cP and 5353 cP; breakdown between 6671 cP and 10194 cP; final viscosity between 3101 cP and 5867 cP; setback viscosity between 152 cP and 2803 cP. Peak time varied between 3.4 seconds and 4.1 seconds, and pasting temperature ranged between 73.2°C and 78.9°C. The developed products i.e. bread at 30% sweet potato flour inclusion and cakes & cookies upto 80% sweet potato flour inclusion exhibited good sensory and consumer acceptability. While increase in amount of sweet potato flour led to firmer textures and reduced sensory acceptance, moderate inclusion (up to 10-12.5%) offered a good balance between optimizing substitution and maintaining consumer preferences. The proximate composition and texture of bread, cookies, and cakes made from sweet potato flour (Naspot 13 & *Kasanda*) varied according to the formulation. These products exhibited good sensory and consumer acceptability comparable to those made with 100% wheat flour. The vitamin A and beta-carotene content were notably higher in products derived from Naspot 13 (orange-fleshed variety). The formulated meal and porridge, which included silverfish, egg, and milk powders, had varying protein content averaging 15%. Sensory acceptability varied based on milk powder and silverfish content. In conclusion, the selected Ugandan sweet potato varieties (both local and hybrid) demonstrated favorable functional properties and can be effectively used to produce high-quality baked products at high levels of wheat substitution, especially in cakes and cookies.

Keywords: characterization, chemical composition, local and hybrid varieties, product development, starch characterization, sweet potatoes.

CHAPTER ONE

INTRODUCTION

1.1. Background

Sweet potatoes (*Ipomoea batatas L.*) are a staple root crop widely consumed in developing nations (Makini *et al.*, 2018; Burri, 2011). Despite their nutritional value and versatility, sweet potatoes remain an underexploited food crop (Oluoch, Lagat, & Langat, 2016). As of 2009, developing countries produced approximately 131 million tonnes of sweet potatoes annually, cultivated on around nine million hectares, resulting in an average yield of 13.7 tonnes per hectare (FAOSTAT, 2009). According to Makini *et al.* (2018), sweet potatoes rank fifth in importance among food crops in developing countries, following cassava, maize, rice, and wheat. Globally, they rank seventh, with Asia contributing 76% and Africa 19.5% of total production. The leading producers include China, Nigeria, Tanzania, Indonesia, and Uganda (FAO, 2015). When properly utilized, sweet potatoes can contribute to a healthy and sustainable diet, requiring less water compared to other staple foods like wheat and rice (Mekonnen & Hoekstra, 2011).

Sweet potato varieties differ widely in color, nutritional content, and preferred uses. Among the most notable varieties globally are the orange-fleshed sweet potatoes, which are valued for their high beta-carotene content, crucial for overcoming vitamin A deficiency (Low *et al.*, 2007). Other popular varieties include purple-fleshed sweet potatoes, have high anthocyanins levels and have been shown to possess antioxidant properties (Truong *et al.*, 2018). In the United States, varieties such as ‘Beauregard’ and ‘Covington’ are commonly cultivated, both known for their high yields and adaptability (Villordon *et al.*, 2009). Meanwhile, Asian varieties like ‘Japanese Murasaki’ and ‘Satsuma-imo’ are prized for their unique flavor and texture, often used in traditional dishes in Japan (Zhang *et al.*, 2020). In Africa, the ‘Ejumula’ and ‘Kabode’ orange-fleshed varieties have been promoted for their nutritional benefits, especially in regions prone to deficiency in vitamin A (Low *et al.*, 2017).

In Uganda, sweet potatoes are the fourth most significant crop, with estimated production at 1.8 million tonnes (Tinyiro & Mayanja, 2018). The leading producer is the Teso sub-region (Olupot *et al.*, 2014; Uganda Bureau of Statistics (UBOS), 2014; Muwanga & Ssemakula, 2011). The Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) reports that sweet potatoes are cultivated across all regions, occupying 55% of arable land dedicated to root and tuber crops, with

the Eastern region alone accounting for 47%. Other producing districts include Iganga (Eastern), Nakasongola (Central), Gulu (Northern), and Kyenjojo (Western) (Tinyiro & Mayanja, 2018). Given their high yields and potential economic returns, sweet potatoes can significantly enhance food security in Uganda and support industrial processing for value-added products.

Among the varieties cultivated, the orange-fleshed sweet potato is notable for its abundant vitamin A content, while other varieties, such as the pale-fleshed cultivars (Dimbuka, Sukali, Tanzania, and Kawogo), are favored for their taste, high dry matter content, and shelf stability. However, despite their nutritional advantages, orange-fleshed varieties are often less preferred due to perceived inferior taste, lower dry matter content, and higher perishability (Tinyiro & Mayanja, 2018).

Research on value addition for sweet potatoes in Uganda is limited, resulting in minimal industrial processing of the crop. Globally, some innovations have emerged, such as a ready-to-drink sweet potato beverage developed with lemon juice and maize malt (Sohail *et al.*, 2013), extruded sweet potato snacks utilizing recycled materials (Aksenova & Kulikova, 2019), and dehydrated mashed sweet potato snacks (Farnsworth, Ogden, & Pike, 2003). Nonetheless, the local market still lacks commercially available, shelf-stable sweet potato products.

To address this gap, there is a pressing need to develop more value-added options for sweet potatoes, creating new opportunities for their utilization. Therefore, this project aims to develop and characterize products from selected Ugandan sweet potato varieties.

1.2 The problem and justification

1.2.1 Problem Statement

The focus on Uganda's sweet potato value chain currently primarily emphasizes primary production (Muwanga & Ssemakula, 2011). Uganda is among the top five producers of sweet potatoes in Africa, with production of about 2.9 million metric tons annually as of 2020 (FAOSTAT, 2022). However, spoilage rates of sweet potatoes are as high as 30% due to their perishable nature and inadequate storage facilities (Nakanyike, 2014; Muwanga & Ssemakula, 2011).

Despite this significant production, value addition to sweet potatoes remains limited, primarily restricted to simple processed products like dried chips, chunks, and flour (Evans School of Public Affairs EPAR, 2013). Production of high value products such as potato chips, noodles, candies, desserts, baked goods, and beverages, is largely absent in Uganda's market. This constrains the industrial applications of sweet potatoes.

Moreover, it is noteworthy that scanty information on the physico-chemical attributes of sweet potatoes grown in Uganda, such as texture, starch content, polyphenol levels, and vitamin A content is available. Understanding the starch characteristics such as amylose, resistant starch, swelling power, pasting properties, and solubility is essential for improving the quality and textural attributes of sweet potato-based food products (Gafuma, Mugampoza, & Byarugaba-Bazirake, 2018), ultimately affecting sensory qualities and consumer acceptability. These gaps in knowledge further constrain the ability to develop sweet potato products that meet both consumer preferences and industrial standards.

There is also scanty information on the physico-chemical attributes of locally grown sweet potatoes, such as starch and its characteristics, polyphenol levels, and vitamin A content. Understanding the starch characteristics such as amylose, resistant starch, swelling power, pasting properties, and solubility is essential for predicting the textural and qualitative attributes of sweet potato-based food products (Gafuma, Mugampoza, & Byarugaba-Bazirake, 2018). These gaps in knowledge further constrain the ability to develop sweet potato products that meet standards.

Therefore, this study focussed on the characterization and development of products from selected sweet potato varieties grown in Uganda.

1.2.2 Justification

This study was strategically aligned with Uganda's National Development Plan III (NDP III, 2020), particularly Chapter 17, Section 17.3, which emphasizes Innovation, Technology Development, and Transfer. By targeting on development and characterization of sweet potato products, the study was in support of the government's commitment to harnessing innovation for economic growth.

Additionally, the project addresses the critical goals of import substitution and the promotion of local manufacturing, as outlined in Chapter 4, Section 4.6.3 of the NDP III. By creating value-

added sweet potato products, we can reduce dependency on imported processed foods and stimulate local industries.

The potential for industrial processing of sweet potatoes presents numerous opportunities for both Ugandans and global consumers, including the production of baked goods like cakes, cookies & bread, juices, infant meals, and other innovative products. The rise of middle-income earners, coupled with the growth of supermarkets and the fast-food sector, creates a favorable environment for high-value sweet potato products. This trend highlights the significant economic and industrial potential of sweet potatoes as a raw material.

Moreover, research into sweet potato product development aligns with the government's broader objectives to enhance the value of agricultural produce, job creation and food security thereby contributing to the industrial and economic development of Uganda.

1.3 Objectives

1.3.1 General Objective

To develop and characterize high-value products, including bread, cakes, cookies, instant porridge and meal, from selected locally grown sweet potato varieties.

1.3.2 Specific Objectives

1. To determine the pulp and skin color, as well as key chemical components (including dry matter, beta-carotene, vitamin A, polyphenols, fat, protein, moisture, ash, sugars, and carbohydrates) of selected varieties of sweet potatoes both local (*Sukali, New Kawogo, Mubalila Bbali, Njule, Nakakande, and Kasanda*) and hybrid (Narospot 1, Naspot 12, Naspot 8, and Naspot 13).
2. To investigate the physicochemical characteristics (water-holding capacity, solubility, swelling power, digestible & resistant starch content, amylose content, and pasting properties) of starch extracted from both local and hybrid sweet potato varieties
3. To develop and characterize specific sweet potato-based products (bread, cakes, cookies, meal and porridge) from selected local and hybrid sweet potato varieties.

1.3.3 Hypotheses

1. There are no differences in the pulp and skin color, as well as the chemical composition (dry matter, beta-carotene, vitamin A, polyphenols, fat, protein, moisture, ash, sugars, and carbohydrates), between local and hybrid sweet potato varieties.
2. The physicochemical characteristics of starch (water-holding capacity, swelling power, solubility, digestible and resistant starch content, amylose content, and pasting properties) do not differ significantly between local and hybrid sweet potato varieties.
3. The quality and consumer acceptability of sweet potato-based products (bread, cakes, cookies, and porridge) developed from local and hybrid sweet potato varieties do not differ significantly from those of wheat-based products.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Classification of Sweet Potatoes

The sweet potato (*Ipomoea batatas L.*), a member of the Convolvulaceae family, is traced back to Central and South America, particularly in the areas that now encompass Peru and Ecuador. Genetic and archeological studies suggest that its domestication dates back over 8,000 years, making it one of the oldest known crops. Early cultivations of sweet potatoes spread throughout the Americas, and with European exploration, the crop was introduced to Africa, Asia, and Oceania (Zhang *et al.*, 2023; Roullier *et al.*, 2018).

Sweet potatoes are classified by various morphological traits, including skin and flesh color. The colors are often linked to specific nutritional content, with orange-fleshed varieties being rich in beta-carotene and purple-fleshed varieties high in anthocyanins, powerful antioxidants (Woolfe, 2021). They are also classified into two major categories: "moist-fleshed" and "dry-fleshed" types. Moist-fleshed varieties tend to be softer and sweeter when cooked, while dry-fleshed types have a more starchy texture. The growth habit of sweet potato vines varies from prostrate to erect, which influences cultivation practices and yield potential. Furthermore, sweet potato plants display differences in flowering behavior, with some cultivars flowering readily under local conditions, while others rarely do so (CIP, 2013). The flowering ability of sweet potatoes is important for breeding programs, as it allows for the selection and development of new cultivars with improved traits.

A biological aspect of sweet potatoes is their underground storage roots. These roots are the primary storage organs for carbohydrates, starch, and other nutrients, with varying levels of amylose and amylopectin, which influence their cooking properties and suitability for different food products. Starch content and composition are important in evaluating the texture, digestibility, and processing potential of sweet potatoes. Varieties with higher amylose content tend to have firmer textures, which are preferred for certain traditional products like *amukeke* (dried sliced tubers) and *kasende* (sweet potato flour) (Nakanyike, 2014).

The biological resilience of sweet potatoes also makes them an essential crop for food security. Sweet potatoes are highly adaptable to different agro-ecological zones, tolerating drought, poor soil fertility, and diseases like sweet potato virus disease (SPVD) and sweet potato weevil (*Cylas* spp.). However, OFSP varieties are more susceptible to spoilage due to their higher moisture content and lower dry matter levels compared to white-fleshed varieties, which are more drought-resistant and have longer shelf lives (Kapinga *et al.*, 2007). This biological diversity within sweet potato cultivars allows farmers to select varieties that meet specific needs for nutrition, profitability, and resistance to environmental stresses.

In sub-Saharan Africa and Uganda, sweet potato is a primary staple food, with local varieties adapted to different ecological zones. The introduction of orange-fleshed sweet potato (OFSP) varieties has contributed in addressing vitamin A deficiencies, as these varieties are biofortified with higher beta-carotene content, which is crucial for improving public health outcomes in regions with high malnutrition rates (Low *et al.*, 2022).

2.2 Varieties of Sweet Potatoes in Uganda

The cultivars in Uganda are primarily distinguished by their flesh colors, tuber shapes, and other biological traits (Adeyemi & Salaam, 2015). The tubers exhibit a series of flesh colors, as white, yellow to dark orange, depending on the carotenoid content, which directly influences the nutritional value, particularly beta-carotene levels (Vimala, Nambisan, & Binu, 2011). Orange-fleshed sweet potato (OFSP) varieties, high in beta-carotene, are promoted for their high vitamin A content, addressing nutritional deficiencies, especially in children and pregnant women (Kapinga *et al.*, 2007).

In Uganda, approximately 40 newly introduced OFSP cultivars have been tested and accepted by farmers and consumers across East Africa, South Africa, and Mozambique (Kapinga *et al.*, 2007). Notable OFSP varieties produced in Uganda include NASPOT 10, NASPOT 9, SPK 004, and Ejumula. Varieties with Yellow flesh include Tanzania and Naspot 1, whereas varieties with white flesh such as New Kawogo, Nakakande, Dimbuka, and Ndikirya N'omwami, are widely grown for their superior dry matter content and taste (Hortz *et al.*, 2012).

While OFSP is planted for its nutritional benefits and potential profitability, many farmers express dissatisfaction due to its high spoilage rate, poor dry matter content, and weak flavor. Conversely, white-fleshed varieties, favored by over 86% of Uganda's sweet potato farmers, are recognised for their high dry matter content, pleasant taste, and versatility in food processing. These cultivars are predominantly used to produce dried sliced tubers (*amukeke*), *kasende* (sweet potato flour), and fresh roots (Nakanyike, 2014). The balance between nutritional content and agricultural traits such as spoilage resistance, dry matter content, and consumer preferences continues to shape the cultivation and use of different sweet potato varieties in Uganda.

2.2.1 Physico-Chemical and Nutritional Traits of Sweet Potato Cultivars

The physical characteristics of the crop's cultivars vary significantly, with flesh colors predominantly ranging from white to orange (Loebenstein & Thottappilly, 2009). The varieties present a range of appearances, including yellow, white, purple, red and orange (Ingabire & Vasanthakalam, 2011). White-fleshed varieties tend to have lower sweetness and moisture, while orange-fleshed varieties are characterized by higher sweetness and moisture content. White-fleshed cultivars possess a drier texture and maintain firmness even after cooking, due to lower beta-carotene and higher dry matter content. In contrast, orange and varieties with red flesh are rich in beta-carotene.

2.2.1.1 Proximate Composition

Proximate composition refers to the key nutritional components like moisture, protein, lipids, fiber, ash, and carbohydrates. These components vary depending on the cultivation conditions, cultivar and preparation methods. Sweet potatoes contain relatively higher moisture content, ranging between 70% to 80%, while dry matter content can vary significantly across different cultivars (Hazo *et al.*, 2021). The dry matter content is particularly important as it affects the textural quality and processing potential of the sweet potato.

Studies conducted by Mohammad Khairul Alam (2021) and Neela & Fanta (2019) show that sweet potatoes are valuable sources of carbohydrates, contributing approximately 20% of the total weight in fresh tubers. The carbohydrate content consists primarily of starch, which is the main energy-giving component. Sweet potatoes also contain moderate amounts of fiber, which aids digestion.

Protein content is low in the crop, varying between 1.3 g to 2.1 g per 100 g of fresh weight. However, sweet potato leaves contain higher protein levels, making them a valuable protein source (Hazo *et al.*, 2021). Lipid content is minimal, typically around 0.1 g to 0.2 g per 100 g. Despite the low fat content, sweet potatoes contain essential fatty acids that contribute to overall health.

Below is an updated table showing the proximate composition of sweet potatoes, incorporating data from recent studies.

Table 2. 1. Proximate Composition of Sweet Potatoes (100 g)

Component	Raw Sweet Potato	Cooked Sweet Potato (Skin)
Energy	86.00 kcal	90.00 kcal
Water	77.28 g	75.78 g
Protein	1.57 g	2.01 g
Total lipid (fat)	0.05 g	0.15 g
Ash	0.99 g	1.35 g
Carbohydrate	20.12 g	20.71 g
Fiber, total dietary	3.00 g	3.30 g
Sugars	4.18 g	6.48 g
Starch	12.65 g	7.05 g

Source: Hazo *et al.* (2021); Neela & Fanta (2019); Mohammad Khairul Alam (2021)

2.2.1.2 Mineral Composition of Sweet Potato Roots

Sweet potatoes are sources of essential minerals (magnesium, phosphorus, calcium, potassium, and iron). The mineral content varies by cultivar and environmental factors, such as soil type and farming practices. Orange-fleshed sweet potatoes (OFSP) are particularly high in iron and zinc, making them a valuable tool in combating micronutrient deficiencies in regions where malnutrition is prevalent (Kivuva *et al.*, 2014).

Table 2. 2. Mineral Composition of Sweet Potatoes (mg/100 g)

Mineral	Raw Sweet Potato	Cooked Sweet Potato (Skin)
Calcium, Ca	30.00	38.00
Iron, Fe	0.61	0.69
Magnesium, Mg	25.00	27.00
Phosphorus, P	47.00	54.00
Potassium, K	337.00	475.00
Sodium, Na	55.00	36.00
Zinc, Zn	0.24	0.30

Source: Kivuva *et al.* (2014); Neela & Fanta (2019); Hazo *et al.* (2021)

Potassium is the most abundant mineral in sweet potatoes, playing a crucial role in regulating blood pressure and fluid balance in the body. Iron, particularly in OFSP varieties, contributes to hemoglobin production and helps in preventing anemia, especially in vulnerable populations.

2.2.1.3 Phytochemicals of Sweet Potatoes

Sweet potatoes are rich in various phytochemicals that are associated with numerous health-promoting effects. These compounds include carotenoids, anthocyanins, polyphenols, and flavonoids, all of which exhibit antioxidant activity. Orange-fleshed varieties of sweet potatoes are particularly notable for their high levels of beta-carotene, a precursor to vitamin A. This nutrient is critical for maintaining healthy vision, enhancing immune response, and promoting skin health (Neela & Fanta, 2019).

Among these phytochemicals, carotenoids, especially beta-carotene, are some of the most researched in sweet potatoes. Studies have found that the beta-carotene content in sweet potatoes can vary significantly, ranging from 709 µg to 11,509 µg per 100 g, depending on the specific variety and growing conditions (Vimala *et al.*, 2011). Additionally, purple-fleshed sweet potatoes are rich in anthocyanins, which are potent antioxidants linked to a reduced risk of chronic diseases, such as heart disease and certain cancers.

Table 2. 3. Phytochemical Composition of Sweet Potatoes (100 g)

Phytochemical	Raw Sweet Potato	Sweet Potato (Skin)
β -Carotene	8509 μ g	11509 μ g
α -Carotene	7 μ g	43 μ g
Anthocyanins	40 mg	50 mg
Polyphenols	80 mg	90 mg
Flavonoids	20 mg	25 mg

Source: Neela & Fanta (2019); Mohammad Khairul Alam (2021)

Carotenoids and anthocyanins are sensitive to processing conditions, with losses occurring due to exposure to heat, light, and air. Proper handling and processing methods, such as steaming or baking, can help retain these valuable phytochemicals, thereby maximizing their health benefits (Feidor & Burda, 2014).

2.3 Sweet Potato Production

Sweet potato (*Ipomoea batatas L.*) is a globally important root crop, ranking seventh among food crops worldwide in terms of production volume. In 2019, global production of sweet potatoes reached approximately 92 million metric tonnes (FAOSTAT, 2020). Asia is the leading producer, contributing around 76% of the global total, with China alone accounting for over 55% of global production. Africa is the second-largest producer, contributing about 19.5% of the global sweet potato supply, with key producing countries including Nigeria, Tanzania, and Uganda (FAO, 2015).

Sweet potato production in sub-Saharan Africa is of particular significance due to its profound impact on the region's food security, nutrition, economy, and resilience to climate change. The importance of sweet potato in Africa extends beyond its role as a food crop, influencing social and economic structures, public health, and agricultural sustainability. The leading producers of sweet potatoes in Sub-Saharan Africa include Nigeria, Uganda, Tanzania, Ethiopia, Malawi and Kenya are leading producers, with sweet potatoes being a crucial staple for food security and a means of income generation (Low & Thiele, 2020). In East Africa, sweet potato production is vital due to its adaptability to varying climates and its role in mitigating food insecurity, particularly in periods of drought (Makini *et al.*, 2018).

In Uganda, sweet potato is cultivated across all regions, with the Eastern region being the largest producer. Specifically, areas such as Soroti, Jinja, Kumi, and Kamuli contribute the largest quantities, approximately 847,139 metric tonnes (MT) annually. The Western region is the second-largest producer with 366,297 MT, followed by the Central region, which produces 312,405 MT. Northern Uganda has the lowest production levels at 292,932 MT (Uganda Bureau of Statistics, 2014). Key districts for sweet potato cultivation include Yumbe, Amuru, Moyo, Oyam, Adjumani, and Arua (Uganda Bureau of Statistics, 2014).

Table 2. 4. Production of Sweet Potato in Regions of Uganda (2018-2022)

REGION	2018 (MT)	2019 (MT)	2020 (MT)	2021 (MT)	2022 (MT)
Eastern	850,000	860,000	870,500	882,000	890,000
Western	365,000	368,000	370,000	372,500	374,000
Central	310,500	315,000	318,000	320,000	322,000
Northern	290,000	292,000	294,000	296,500	299,000

Source: FAOSTAT (2018-2022), Abongo, Omayio, & Okoth (2016).

A survey conducted in the Kumi district revealed that 99% of female farmers grow sweet potatoes for both food security and commercial purposes, whereas male farmers tend to prioritize income generation. According to the Uganda Bureau of Statistics (2014), sweet potatoes are increasingly recognized as vital for food security, especially during periods of famine and in the face of rising global food prices. This crop plays a critical role in enhancing resilience among smallholder farmers, particularly in rural regions.

2.4 Consumption of sweet potato

Sweet potato (*Ipomoea batatas L.*) holds substantial importance as a food crop, especially in regions such as Sub-Saharan Africa, the Pacific Islands, and parts of Asia (Barrera & Picha, 2014). Despite this, its global consumption remains relatively modest. For instance, the average annual consumption per capita was 7.97 kg in 2011, 8.01 kg in 2010, and 8.22 kg in 2009 (FAOSTAT, 2015). This suggests that, on a global scale, other staples like rice, wheat, and maize are more widely consumed, while sweet potato occupies a more specific role in regions where it serves as a vital food security crop.

Asia, particularly China, accounts for the highest consumption levels of sweet potato due to its significant production. In these regions, the crop is used extensively for both human consumption

and livestock feed. In Sub-Saharan Africa, the per capita consumption is far above the global average, underscoring its critical role in maintaining food security. East Africa, in particular, depends heavily on sweet potatoes. In countries such as Uganda and Tanzania, the crop is indispensable, thriving in various agro-ecological environments and acting as a key food source during periods of scarcity.

In Uganda, the annual per capita consumption ranges from 90 to 100 kg, positioning sweet potatoes as one of the most consumed root crops in the country (Loebenstein & Thottappilly, 2009). This high consumption reflects the central role sweet potatoes play in both rural and urban communities as a reliable food source, especially during lean seasons. The crop is consumed in several forms, including boiling, steaming, and roasting, making it a household staple in East Africa.

In Uganda, commercial farmers often supply large institutions such as prisons, schools, and hospitals, where bulk cooking is prevalent. Additionally, food security programs rely heavily on sweet potato because of its cost-effectiveness and nutritional value. Reports from Food Net Uganda and various sweet potato trade associations indicate that the crop is a popular choice among low-income households, both in rural and urban settings, particularly during times of food insecurity. Its versatility, adaptability to various soil and climatic conditions, and affordability make sweet potato a crucial crop for both subsistence farmers and commercial ventures alike.

2.5 Storage of Sweet Potatoes

Postharvest handling of sweet potatoes is a critical process that significantly influences their market quality, shelf life, and nutritional value (Hall & Devereau, 2000). Proper postharvest practices are essential to prevent significant losses, maintain product quality, and maximize the economic potential of sweet potatoes, particularly for their use in value-added products like bakery goods.

The postharvest process starts with curing, which is a critical step that requires storing sweet potatoes in a warm, humid environment typically around 85°F with 90-95% relative humidity—for a period of 4 to 7 days (Hall & Devereau, 2000). This curing process helps the sweet potatoes heal any cuts or bruises sustained during harvest, minimizing the chances of microbial infections, weight loss, and spoilage. Moreover, curing improves sugar development, which improves both the flavor and texture of sweet potatoes. After curing, sweet potatoes should be stored in cooler,

controlled conditions, typically between 55-60°F with 85-90% humidity. This helps maintain their quality and prevents sprouting, decay, and microbial attacks during storage (Hall & Devereau, 2000).

Postharvest losses are a significant challenge for sweet potato producers in developing countries. These losses can range between 20-40%, primarily due to poor storage practices, mechanical damage during handling and transportation, and lack of access to appropriate storage technologies (FAO, 2013). In Uganda, many farmers store sweet potatoes for a week or less after harvesting (Okonya, Mwanga, Jurgen, & Syndiku, 2014). White-skinned cultivars can last up to 19 weeks when stored in traditional methods, such as clamps or pits (covered above-ground mounds), but this is not always effective in preventing spoilage (Engoru, Mugisha, & Bashaasha, 2005). Some farmers in Eastern Uganda have reported storing sweet potatoes for up to 138 days in pits, though this varies widely depending on the climate and storage conditions (Engoru, Mugisha, & Bashaasha, 2005).

The high moisture content of certain cultivars, especially orange-fleshed sweet potatoes (OFSP), increases their susceptibility to postharvest deterioration, contributing to significant losses during transportation and storage. This rapid spoilage, coupled with limited infrastructure and inadequate cold chain facilities, has prompted a need for value-added processing, such as converting sweet potatoes into bakery products, flour, and other longer-lasting goods. Transforming sweet potatoes into processed products not only reduces postharvest losses but also enhances the economic value of the crop by creating products with a longer shelf life.

Postharvest handling during transportation is also crucial. Sweet potatoes should be protected from extreme temperatures and mechanical damage by using ventilated crates or bins that prevent excessive pressure, bruising, and physical damage. Minimizing handling steps and ensuring gentle handling can further reduce losses (Andrade *et al.*, 2009). Postharvest treatments, such as applying fungicides, can protect sweet potatoes from diseases, though these treatments must adhere to safety standards and consumer preferences.

Postharvest sorting and grading based on size, shape, and absence of defects are vital for ensuring that only the best quality produce reaches the market. Properly sorted and graded sweet potatoes

can be used to develop products like bread, cakes, cookies, and porridge. These products have a longer shelf life than fresh sweet potatoes and help to offset some of the losses incurred during the storage of the raw tubers.

Given the high postharvest losses and perishability of sweet potatoes, particularly OFSP, transforming them into value-added products like bakery items can significantly extend their usability. These processed products offer more stable, profitable market opportunities for farmers and entrepreneurs, contributing to food security and reducing waste. In addition, improved postharvest handling practices, such as curing, controlled storage, and gentle handling, are critical for maintaining the quality of sweet potatoes from the field to the consumer's table, enhancing both their nutritional value and market appeal (Nabubuya, Birungi, & Muzira, 2018).

2.6 Nutritional and Health Benefits of Sweet Potatoes

Sweet potatoes (*Ipomoea batatas L.*) are highly nutritious root vegetables that offer a broad range of health benefits, making them an important part of a balanced diet. Rich in essential vitamins, minerals, dietary fiber, and antioxidants, sweet potatoes contribute to overall health and are useful in preventing various chronic illnesses. In Uganda and many other regions, sweet potatoes serve as a staple food, delivering crucial nutrients to the population.

One of the main nutritional strengths of sweet potatoes, especially the orange-fleshed varieties, is their high vitamin A content. A single serving can provide more than 100% of the recommended daily allowance, primarily in the form of beta-carotene, a precursor to vitamin A. This nutrient is crucial for maintaining eye health, boosting the immune system, and promoting healthy skin (Low *et al.*, 2017). Additionally, beta-carotene, a powerful antioxidant, plays a role in reducing oxidative stress, which may lower the risk of certain cancers and cardiovascular diseases (Tanumihardjo *et al.*, 2010). As the body converts beta-carotene into vitamin A, it supports good vision, helps prevent night blindness, and lowers the risk of age-related macular degeneration (Tang *et al.*, 2005). Furthermore, purple-fleshed sweet potatoes, which are rich in anthocyanins, provide additional protection for eye health by combating oxidative stress in the retina.

Sweet potatoes are also a rich source of dietary fiber, which is essential for maintaining a healthy digestive system. Fiber helps regulate bowel movements and supports gut health by fostering the growth of beneficial gut bacteria (Slavin, 2013). Moreover, a fiber-rich diet can lower the risk of

heart disease, type 2 diabetes, and obesity by helping regulate blood sugar levels and promoting satiety, which aids in weight management (Anderson *et al.*, 2009).

In addition to fiber, sweet potatoes are packed with vitamins C and E, both of which are known for their immune-boosting properties. Vitamin C acts as an antioxidant, playing a key role in the production of white blood cells, which strengthens the body's ability to fight off infections. It also enhances iron absorption, helping to prevent anemia. Vitamin E, another antioxidant, helps protect cells from oxidative stress and supports overall immune function (U.S. Department of Health & Human Services, 2020).

The antioxidants present in sweet potatoes, including beta-carotene, vitamin C, and anthocyanins (found in purple-fleshed varieties), offer strong anti-inflammatory benefits. Chronic inflammation is a contributing factor to numerous health conditions, such as heart disease, cancer, and autoimmune disorders. Incorporating sweet potatoes into one's diet may help reduce inflammation and guard against these diseases (Mishra *et al.*, 2018).

Despite being a starchy vegetable, sweet potatoes have a lower glycemic index (GI) compared to white potatoes, meaning they cause a slower increase in blood sugar levels. This makes them a better option for individuals with diabetes or those who wish to maintain stable blood sugar levels (Henry *et al.*, 2006). Additionally, the fiber content in sweet potatoes helps slow glucose absorption, further aiding in blood sugar regulation.

Sweet potatoes are also a good source of potassium, an essential mineral that plays a critical role in fluid balance, nerve transmission, and muscle function. Potassium helps regulate blood pressure by counteracting the effects of sodium, thereby lowering the risk of hypertension (He & MacGregor, 2008).

The vitamins A and C found in sweet potatoes also benefit skin health. Vitamin A aids in skin cell regeneration and repair, while vitamin C is crucial for collagen production, helping to maintain skin elasticity and reduce the appearance of wrinkles (Pullar J. M, 2017). The antioxidants in sweet potatoes additionally protect the skin from damage caused by ultraviolet (UV) radiation and environmental pollutants.

As a source of complex carbohydrates, sweet potatoes provide sustained energy. These carbs are broken down more slowly, leading to a gradual release of glucose into the bloodstream. This makes

sweet potatoes a great choice for athletes or anyone seeking long-lasting energy throughout the day (Rodriguez *et al.*, 2009).

The combination of fiber, potassium, and antioxidants in sweet potatoes supports heart health. Potassium helps regulate blood pressure, fiber contributes to lowering cholesterol levels, and the anti-inflammatory properties of sweet potatoes help protect the cardiovascular system, reducing the risk of heart disease (Slavin, 2013).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials and Equipment

The materials utilized in this study included selected varieties of sweet potatoes both local (*Sukali*, *New Kawogo*, *Mubalila bbali*, *Njule*, *Nakakande* and *Kasanda*) and hybrid (Naspot 1, Naspot 12, Naspot 8 and Naspot 13). The laboratory reagents used included deionized water, methanol, distilled water, potassium hydroxide, ethanol, sodium hydroxide, hydrochloric acid, pectinase, Tris maleate buffer, phenol, and sulfuric acid.

The equipment used in this study included a dough mixer (Macadams model: SM-5), a dough prover (Macadams model: PR1335), an oven (Macadams model: Macadams M120), a bread slicer (Macadams model: 4710), a texture analyzer (model: TVT 6700), a Kjeldahl digestion flask, a spectrophotometer, a Chopin Mixolab 2 (Noserie 696), conical Falcon tubes, a hot air oven (Yamato, DG 400C, Japan), a grinder (Geepas, GSB 35362, Japan), a mortar and pestle, an ADJ 100-4 balance (KERN & SOHN GMBH, Germany), and an evaporator (Model R 3.10).

3.2 Research design

Local and hybrid varieties were selected to determine if any differences exist between them. For determination of chemical composition, fresh samples were used from which samples were drawn for analysis. For determination of texture (firmness), raw, freshly cooked and cooled sweet potatoes were used. For characterization of chemical composition, fresh sweet potatoes were used. Starch extraction was also done using fresh sweet potatoes direct from the garden. The extracted starch was dried before being used for characterization. The results of chemical composition, texture and starch characterization were examined and two varieties selected for product development. Products were developed from Naspot 13 and *Kasanda* varieties. Naspot 13 (orange fleshed) was selected because of high beta carotene levels and Vitamin A whereas *Kasanda* was selected due to its wide availability and white color (in contrast to Naspot 13). Products developed included bread, cakes, cookies, and instant porridge and a meal powder. The developed products were characterized in terms of texture, nutritional attributes, Vit A, carotenoids, and sensory attributes and acceptability.

3.3 Raw material collection and treatment

In the preliminary studies to find out the chemical composition of the sweet potatoes and starch characterization, ten (10) locally available both local and hybrid varieties were purchased from a large-scale multiplication farmer at Bombo in Luweero district. These included *Sukali*, *New Kawogo*, *Mubalila bbali*, *Njule*, *Nakakande* and *Kasanda* for the local varieties and Narspot 1, Narspot 12, Narspot 8 and Narspot 13 for hybrid varieties. These were harvested and brought to the laboratory fresh where they underwent various treatments for the various experimental treatments and analyses. For product development, both Narspot 13 (orange fleshed sweet potato) and *Kasanda* (white fleshed weet potato) varieties were used. These were obtained from multiplication farms at Namulonge Agricultural Crops Research Institute (NACRI), Namulonge.

3.4 Pulp & skin color and chemical composition of the selected local and hybrid sweet potato varieties.

3.4.1 Skin and pulp color identification

The ten (10) sweet potato varieties purchased from a multiplication farm at Bombo, in Luweero district, Uganda were washed properly, drained and wiped dry before being placed on a table. The different sweet potato varieties were carefully observed for skin color (appearance). The identified color or appearance was recorded for each variety. The sweet potatoes were also cut into cross sections and observed for flesh (pulp) color. The color of their skin and pulp identified were recorded.

3.4.2 pH determination

40 g of peeled sweet potato from each variety was grated into a blender. Then 160 ml of water was added and sample crushed. The suspension was put into a falcon conical tube then vortexed for 4 minutes. The mixture was then centrifuged at 5000 rpm for 4 minutes and its supernatant used to measure the pH of the sample.

3.4.3 Dry Matter Content

The AOAC technique (1999) was used to analyze the dry matter content. Sweet potatoes from each of the 10 varieties were peeled and carefully sliced to about 1 – 2 mm. Then about 100 g of sliced sweet potatoes were weighed into dry pre-weighed petri-dishes and immediately made to dry in an air-drying oven (Yamato, DG400C, Japan) at temperature of 105°C for 5 h. The dried

sweet potatoes in the petri dishes were cooled in a dessicator to room temperature before being weighed again. The dried sweet potatoes were carefully ground in a grinder (Geepas, GSB5362, Japan) to a fine powder. The fine powder was further made to dry at 105°C for 5 h and then cooled in a desiccator to room temperature before being weighed again. The formula below was then used;

% Dry matter content

$$= \frac{(\text{Weight of sliced sweet potatoes before drying} - \text{weight of dried sweet potato flour})}{W \text{Weight of sliced sweet potatoes}}$$

× 100 (3.1)

Beta Carotene

The extraction and analysis of β -carotene were performed by placing 1 g of flour samples into 5 ml of absolute methanol at room temperature for a duration of 2 hours, following the method outlined by Aremu & Nweze (2017). The procedure was conducted in the dark to ensure complete extraction and minimize the degradation of β -carotene due to light exposure. After the extraction, the β -carotene layer was isolated by adding hexane and separating it through a funnel. Hexane was then added to bring the volume up to 10 ml, and the solution was passed through sodium sulphonate in a funnel to remove any moisture from the layer. The absorbance of the sample was measured at 450 nm, using hexane as a blank. The β -carotene content was calculated using the following formula;

$$\beta - \text{carotene} \left(\mu \frac{\text{g}}{100\text{g}} \right) = \frac{\text{Absorbance} (436 \text{ nm}) \times V \times D \times 100 \times 100 \times (5)}{W} \quad (3.2)$$

where: D = Dilution factor, V = Total volume of extract; and W = Sample weight;

3.4.4 Vitamin A

The Vitamin A content was analysed as per the method reported by (Jadoon, Malik, Qazi, & Aziz, 2013) with modifications. Pharmaceutical solid vitamin A tablet was ground with a sterilized mortar and pestle. Thereafter, 0.5 g of the ground material was weighed with a weighing balance model (KERN ADJ 100-4, KERN & SOHN GmbH, Ziegelei 1,72336 Balingen, Germany) and vitamin A was then extracted twice with 5.0 mL of 80% methanol to a total of 10 mL and vortexed for uniform mixing with a vortex mixer thereafter, 5 mL was then taken off into an empty

50 mL falcon tube where 10 mL of methanol diluted to 80% was further used for dilution. The mixture was wrapped with an aluminium foil to prevent light mediated degradation while in the 50 mL falcon tube. The mixture was added to 1.0 mL of 50% KOH and 2.0 mL of 80% ethanol to saponify it and incubated in a water bath at 45°C for 2 hrs with intermittent mixing. After incubation, 1 ml of distilled water was added to the mixture then re-vortexed. 5.0 mL of absolute petroleum ether was added to the mixture, vortexed and left to settle for five (5) minutes till formation of the two distinct organic layers. The organic layer on top was evaporated to dryness with the help of the rotary evaporator model R 3.10, where the water bath was set at 37°C and rotation of the arm set at 100 r.p.m. The mixture was then vortexed and mixed after adding 5 mL of carrier solution composed of 80% methanol in triton solution in order to re-dissolve it. Similar procedures were used for bread samples. From the solution, 1 mL was pipetted off into a cuvette and absorbances recorded spectrophotometrically at 562 nm with a UV/Vis spectrophotometer (Jenway, 6505, UK).

3.4.5 Polyphenols

Polyphenol content was analysed spectrophotometrically as per the method by Folin–Ciocalteu (Sun, Mu, Xi, Zhang, & Chen, 2014). To 5 g of each sample was added 15 ml of 80% methanol in a crucible and then crushed and blended using a pastel. The mixture from crucible was put into a falcon tube and thoroughly mixed using a vortex machine. The falcon tubes were then placed into a centrifuge at 4°C, at 6000 rpm centrifugation speed (rotations per minute) for 10 min.

1ml of the clear supernatant (sample) was picked and put into a clean falcon tube. 0.6 ml of 10% Trichloro Acetic Acid (TCA) and added 0.5 ml of Folin ciocalteu reagent to the sample and mixed. Incubation was then done in the dark, for 5 minutes at ambient temperature. 1.5 ml of 20% sodium carbonate was added to the mixture to neutralize it and then put in a water bath at 40°C for 30 minutes. The mixture was then cooled for 8 minutes under ambient temperature a spectrophotometer used to read the absorbance at 750 nm.

3.4.6 Protein content

Protein analysis was carried out using the Micro Kjeldahl method as described by AOAC (2000). A 0.2 g sample was wrapped in filter paper and placed into a 250 ml Kjeldahl digestion flask containing boiling magnesium flakes. To promote oxidation, spatula amounts of CuSO₄ and Na₂SO₄ were added to each flask. After digestion, the flasks were allowed to cool and then diluted

with 100 ml of deionized water. A blank control was prepared similarly. For each distillation, 10 ml of the digest was transferred to a distillation flask, followed by the addition of 20 ml of a 2% boric acid solution and two drops of a methylated indicator into the receiving flask placed under the condenser. Then, 35 ml of a 40% NaOH solution was added, and the stopper was quickly replaced. The mixture was distilled, and 30 ml of distillate was collected. Both the sample and blank distillates were titrated using 0.1N sodium chloride solution. The percentage of nitrogen obtained was multiplied by 6.25 to determine the crude protein content.

3.4.7 Fat Content

The fat content was analyzed as described by (AOAC, 2000). Five grams (5g) of each sample (except juice), was wrapped in a filter paper and placed in thimbles for extraction of fat. The thimble was then placed in the soxhlet extraction apparatus connected to the pre-weighed and dried fat extraction flasks containing the extraction solvent and placed on heating mantles and extraction was carried out for eight hours. The apparatus was disconnected and the solvent was evaporated on the rotar vapour and the flask containing the residue was dried at 103 to for three hours. The flask was then cooled for thirty minutes in the dessicator and then weighed and the fat is determined by difference.

$$\% \text{ crude fat} = \frac{(\text{weight of flask} + \text{fat}) - (\text{weight of empty flask})}{\text{weight of sample}} \times 100 \quad (3.3)$$

3.4.8 Moisture Content

Moisture content was analysed as per (AACC, 2000). Accordingly, 5g of sample were put into a dry weighed petri-dish and heated in an electric oven for 5 hours at 105 °C. It was then taken away from the electric oven and put in a desiccator for 30 minutes to cool to ambient temperature. After cooling, sample + petri-dish was weighed and readings recorded. The formula below was used to calculate moisture content,

$$\% \text{ Moisture} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100 \quad (3.4)$$

3.4.9 Ash Content

Ash content of samples was analyzed as per the method detailed by Melon & Pomeranz (1980). A crucible was washed and made to dry in the oven at 100°C for about 15 minutes and thereafter made to cool in a desiccator. The crucible was weighed and about 2 g of the sample was placed in

it then weighed. Thereafter put in a furnace at 550°C for 3 hours. The sample was made to cool in a desiccator and weighed to obtain the ash content.

$$\text{Ash (\%)} = \frac{\text{weight of ash}}{\text{Weight of sample}} \times 100 \quad (3.5)$$

3.4.10 Carbohydrate Content

For carbohydrate analysis, 0.5 g of the fresh sample was homogenized with 10 ml of 80% ethanol, followed by vortexing at 6000 rpm for 10 minutes at 4°C, in line with the modified colorimetric assay method described by DuBois et al. (1956). A 0.5 ml aliquot of the homogenized sample was transferred into three separate test tubes, diluted with 1 ml of deionized water, and then dehydrated using 1 ml of concentrated sulfuric acid. To facilitate the formation of colored complexes, 0.5 ml of 5% (w/v) phenol was added to the furfural compound that resulted from the dehydration process. The concentration of the carbohydrate complexes was then quantified using a spectrophotometer, with absorbance measured at 490 nm, using standard glucose for reference.

3.4.11 Total Sugar Content

The freshly harvested sweet potato was cleaned, peeled, and shredded. 15 ml of an 80% ethanol solution was added, 15 grams of the sample were crushed, and the mixture was then homogenized using a sample homogenizer. Prior to being centrifuged for 10 minutes at 4°C, the mixture was vortexed. After that, 5 ml of distilled water was added to 0.5 ml of the ethanoic clear supernatant. The material was then dehydrated with 1 ml of concentrated H₂SO₄. The development of a gold-colored complex prompted the addition of 0.5 ml of 5% phenol. Using spectrophotometry, the amount of sugars was calculated by comparing the absorbance at 490 nm to a standard curve of glucose.

3.5 Starch extraction and characterization

3.5.1 Starch extraction

The alkaline wet extraction method according to (Zhang, Whistler, Bemiller, & Hamaker, 2005) was used to extract starch with minor modifications. Fresh and healthy medium-sized sweet potato roots per variety were peeled and 200g weighed and sliced into tiny pieces of 2 mm then mixed with 1 litre of 0.05N NaOH solution and macerated to a fine homogenate in a high speed coffee

grinder (Geepas, GCG289, Japan) for about 2 min. The homogenate put together with 5.5 litres of distilled water and screened through a fine nylon cloth with pore size of 50 microns and the filtrate collected and allowed to stand for about. To fully extract the starch, the homogenate was gently and gradually rinsed with 8 litres of water and screened through a fine nylon fabric. The leftovers were thrown away.

The starch suspension (filtrate) was carefully decanted after being allowed to settle for approximately 24 hours at ambient temperature. To eliminate color, the starch sediment was washed again using eight liters of water and a new nylon cloth with a pore size of 50 microns to ensure proper separation of the starch from fibrous material. The starch sediment was then re-suspended and given another 24 hours to settle. This washing procedure was repeated four times for all the samples until a white starch sediment was obtained. The final sediment was rinsed into a 1-liter container and allowed to settle for 24 hours before being decanted and dried for 24 hours at 55°C in an air-drying oven. The dried starch was weighed, ground into a fine powder in a blender, sealed, labeled, and kept for further examination before being placed in clear polythene bags.

3.5.2 Starch characterization

3.5.2.1 Water Holding Capacity (WHC)

According to the procedure outlined by (Bokanga *et al.*, 2002), WHC was analyzed. In order to keep the starch continuously suspended, 0.5g of starch was placed in a falcon tube already weighed. 10 ml of distilled water was then topped up to the mixture and vortexed on an orbital shaker for an hour. The mixture was then centrifuged at 5000 rpm for 10 minutes at a temperature of 4°C. The sediment in the falcon tube was weighed after the supernatant was decanted and done in triplicate. WHC was calculated as;

$$\text{Water Holding Capacity, WHC} = \frac{\text{Wt. of gel formed} - \text{wt. of original sample}}{\text{original sample wt}} \quad (3.6)$$

3.5.2.2 Starch swelling power and solubility

Swelling power and solubility was analyzed as per (Kusumayanti, Handayani, & Santosa, 2015). A 15 ml pre-weighed oven-dried falcon tube containing 0.2g of starch was filled with 10 ml of

distilled water, then tightly closed. The mixture was then vortexed to distribute starch. The starch dispersion in the tube was heated in a water bath at various temperatures (40, 50, 55, 60, 65, 70, 75, 80, 85, and 90 °C) for 30 minutes. After cooling to ambient temperature, the gel and supernatant were separated by centrifuging the mixture at 5000 rpm for 10 minutes at 4°C. In order to test the starch solubility, the supernatant was placed into an already weighed container then dried in the oven at 105°C for 8 hours. At the same time, the starch gel sediment was weighed and swelling power was then determined. This was done in triplicate.

The swelling power was got as the ratio of the weight of the sediment to the original sample weight. The solubility was expressed as a percentage of dried supernatant weight to the original sample.

$$\text{Swelling Power } \left(\frac{\text{g}}{\text{g}}\right) = \frac{\text{Weight of sedimental paste (g)}}{\text{Weight of the sample (dry basis)(g)}} \quad (3.7)$$

$$\text{Solubility (\%)} = \frac{\text{Weight of the dried supernatant}}{\text{Initial weight of the dry starch}} * 100 \quad (3.8)$$

3.5.2.3 Digestible and resistant starch

Digestible starch was determined using AOAC method 2002.02 and AACC method 32-40.01 with modifications. Approximately 100 mg of potato starch was put into a 15 ml Falcon tube. The starch was combined with 10 ml of a 1 M NaCl/0.5 M HCl solution containing 10 mg/ml of pepsin, then left to digest the protein at room temperature (25 °C) for 40 minutes. Tris maleate buffer (pH 6.9) was prepared using 6.05 g in 250 ml of Tris (Hydroxy methyl) amino methane (99.9%) to make a stock solution of 0.2 M Tris maleate and 0.2 M NaOH solution as stock. Then 100 ml of Tris maleate stock and 93 ml of NaOH stock solution was mixed in one beaker to make a stock solution. Distilled water was used to increase the quantity to 400 ml, and 5 M HCl was used to standardize the pH to 6.9. Then, 250 ml of Tris maleate buffer was put to 0.5 g of α -amylase (3000 U/ml). The pepsin incubated solution was centrifuged at 4000 g for 10 min. at 4 °C. To digest pectin and cellulose/hemicellulose, the supernatant was discarded, and the sediment was then treated with 1 ml of pectinase (1000 U/ml) (CAS: 9033-35-6) in phosphate buffer (containing activity for polygalacturonase, pectin lyase, pectin methylesterase, cellulase, and hemicellulase). For 60 minutes, the mixture was left to incubate at 37 °C. The pectinase-incubated solution was once more centrifuged for 10 minutes at a temperature of 4°C at 6000 rpm. The sediment was combined with 5 ml of Tris maleate solution that contained amylase and left to incubate at ambient

temperature for 16 hours after the supernatant was discarded. It was then incubated at 37°C for 1 h and the mixture centrifuged at 4000 g for 10 min at 4°C to remove the insoluble residues. 0.5 ml was drawn from the supernatant, and mixed with 0.5 ml of 5% phenol and 1 ml distilled water added. Then, 1 ml of conc. H₂SO₄ was added and the solution left to stand in the dark for about 10 min to allow for color development before reading the absorbance using a spectrophotometer at 490 nm.

Resistant starch

Tris maleate buffer of pH 4.75 was added to the sediment from the determination of digestible starch as per methods (AOAC method 2002.02 and AACC method 32-40.01), solubilizing the sediment and heating it in the water bath at 90°C for 30 min to gelatinize starch. The gel formed was homogenized using a sample homogenizer before adding amyloglucosidase. 0.3 g of amyloglucosidase was then mixed together to 6 ml of Tris mealate buffer at pH 4.75 and properly mixed in a vortex. The starch gel formed was homogenized using a sample homogenizer. 120 µl of amyloglucosidase solution was added to the mixture and mixed thoroughly in the vortex. The mixture was then incubated at 60°C for 45 min at Ph 4.75 and centrifuged at 4000 g for 10 min at 4°C. The supernatant got was used to analyze for resistant starch. Using the supernatant, 0.5 ml was put into a test tube then 0.5 ml phenol added. Then, 1 ml of distilled water and 1 ml conc. H₂SO₄ was added and allowed 10 min in a dark area for color development. The absorbance was read at 490 nm and a standard curve for determination of glucose concentration was also prepared using glucose monohydrate. Starch concentrations were determined by taking glucose concentration x 0.9.

3.5.2.4 Amylose content

The amylose and amylopectin content were analysed as per the iodine colorimetric procedure as outlined by (Zakpaa, AL-Hassan, & Adubofour, 2010). Approximately 100 mg of sweet potato starch was placed in a volumetric flask, then mixed with 1 ml of ethanol and 10 ml of distilled wate added, thereafter 2 ml of 10% NaOH solution was added and heated at 90°C in the water bath (WNE 45, India). This was done until the solution became clear. Contents in the flask were then left to cool then distilled water added to the mark to dilute it. A 500 ml volumetric flask was filled with 5 ml of the alkaline solution, 100 ml of distilled water, and 3 drops of 6 M HCl to mildly acidify the mixture. Shaking the flask thoroughly mixed the contents before adding 5 ml of iodine

solution and diluting it to the proper strength with distilled water. Using a UV spectrophotometer (LKB Biochrom Ultrospec II, model 4050, Cambridge, England), the solution's absorbance was measured against a blank at 640 nm. A standard curve was prepared for determination of amylose concentration using standard amylose and the resulting regression equation used to determine amylose concentration (Zakpaa *et al.*, 2010). The amylopectin content was then got by difference between 100% and the concentration of amylose.

3.5.2.5 Pasting properties

The pasting properties of sweet potato starch were determined using a Rapid Visco-Analyser (RVA), following the method outlined by Agirinya & Lwe (2015). A sample of 2.5 g of sweet potato starch was weighed and combined with 25 ml of distilled water in a canister. The canister was securely fastened to the RVA, and the starch slurry was mixed thoroughly, first at 960 rpm for 10 seconds to ensure uniform dispersion, followed by 160 rpm for the remainder of the test. The slurry was subjected to a controlled heating and cooling cycle: it was heated from 50°C to 95°C, held at 95°C for 2 minutes, then cooled back to 50°C and held for an additional 2 minutes. Both the heating and cooling rates were maintained at a constant rate of 11.25°C/min. The test was performed in duplicate, ensuring that each suspension was tested under identical temperature-time conditions. Thermocline for Windows software was used to control the RVA and to monitor the temperature-time profile throughout the test. The software provided real-time data on the viscosity changes during the pasting process, allowing for the precise measurement of pasting properties such as peak viscosity, trough viscosity, breakdown, final viscosity, setback, and pasting temperature. These pasting properties were recorded and analyzed to assess the functional characteristics of the starch samples.

3.6 Development of selected sweet potato products

3.6.1 Production of Sweet Potato Flour

To get rid of dirt and soil, the fresh sweet potatoes were properly rinsed. They were cleaned, peeled, and sliced into small pieces before being blanched in potassium metabisulphite for 15 minutes and drying for 72 hours at 60°C. According to (Eke & Kabari, 2010), the dry sweet potato chips were ground into flour. After getting flour, it was put in an airtight container for later usage.

3.6.2 Characterization of sweet potato bread

3.6.2.1 Rheological properties of the sweet potato-wheat dough

Rheology of the sweet potato-wheat dough was performed using a Chopin Mixolab 2 (No Serie 696). The Chopin+ protocol was selected for the analysis. The moisture content of the dough samples was adjusted as follows: 12.3% for 10% OFSP (Orange-Fleshed Sweet Potato), 12.0% for 17.5% OFSP, 11.5% for 25% OFSP, 11.3% for 30% OFSP, and 10.5% for 40% OFSP; similarly, the moisture content for WFSP (White-Fleshed Sweet Potato) dough samples was 12.0% for 10% WFSP, 10.3% for 17.5% WFSP, 9.9% for 25% WFSP, 11.5% for 30% WFSP, and 10.9% for 40% WFSP.

Water absorption capacity (expressed as a percentage of the flour weight) was adjusted to 57.8% for 10% OFSP, 59.6% for 17.5% OFSP, 59.2% for 25% OFSP, 61.1% for 30% OFSP, and 62.4% for 40% OFSP. For WFSP, the water absorption values were set at 54.5% for 10% WFSP, 52.8% for both 17.5% and 25% WFSP, 57.4% for 30% WFSP, and 58.0% for 40% WFSP.

A hydration base of 14% was selected for the tests. A hydration base of 14% was selected for the tests to standardize the moisture content across all dough samples during the rheological analysis. This base ensures consistency in dough preparation, allowing for accurate comparison of the effects of different sweet potato flour (OFSP and WFSP) substitutions on dough behavior. The samples were weighed according to the Mixolab software's specifications as seen in table 3.1.

Table 3. 1. Proportions of samples weighed for rheology

Ratios	Weight of composite flour (g)
10:90 OFSP:WF	46.61
17.5: 82.5 OFSP:WF	48.99
25: 75 OFSP:WF	45.78
30:70 OFSP:WF	45.14
40:60 OFSP:WF	44.38
10:90 WFSP:WF	47.44
17.5: 82.5 WFSP:WF	47.06
25:75 WFSP:WF	46.85
30:70 WFSP:WF	46.30
40:60 WFSP:WF	48.82

OFSP: Orange Fleshed Sweet Potato: WF: Wheat Flour: WFSP: White Fleshed Sweet Potato

The dough mixer was then positioned in the Mixolab housing, the lid was closed, and the test was initiated. The dough sample was introduced using a specially provided funnel, and the injection nozzle was positioned. A torque of 1.1 Nm (Newton-meters) was achieved, and the test proceeded for 45 minutes to monitor the dough behavior.

3.6.2.2 Preparation of sweet potato bread

Runs were generated using design expert software and a preliminary test was done to determine the practicality of bread production from the generated runs. Baking results indicated that combinations of sweet potato (Naspot 13 and *Kasanda*) and wheat flours (SP:W) in the ratio of 0:100, 10:90, 17.5:82.5, 21:79, and 30:70 were possible. Then, these composite flour combinations were sieved to remove any large and other unwanted particles. To each 1kg of the sweet potato-wheat composites, 7g of yeast, 100g of sugar, 7g of salt, 50g of batter and 5g of calcium propionate were added to form a mixture. The mixture was poured into the 5kg capacity Macadams (model: SM-5) mixer and added 500 ml (g) of water. It was then mixed for 8 minutes until the dough developed. Baking tins of ½ kg were greased and 500 g of the molded dough was added. The dough was proofed in the Macadams prover (model: PR1335) for 2 hours and then baked in the rotary Macadams oven (model: Macadams M120) for 30 minutes. The bread was then left to cool for 2 hours and then sliced using a macadams bread slicer (model:4710) and packed in airtight polyethylene bags for later physico-chemical analysis and sensory evaluation.

3.6.2.3 Texture of the sweet potato-wheat bread.

The texture of bread was analysed using a TVT texture analyzer (TVT 6700). The bread was sliced to 50 mm thick slices and 3 slices placed on the measuring stage and centered below the probe. The starting distance of the probe from the sample was 5mm. Firmness, Springiness and cohesiveness of the bread was determined by double cycle compression using a 25mm diameter, rounded edge, stainless steel probe, number. 67.30.26. The measurement data was obtained as soon as the probe reached the pre-set trigger force of 5g. The probe compressed the sample in the first compression to a pre-defined distance of the sample height (20% compression) then paused for 15 seconds for another compression cycle. The probe then returned to its starting position after the second compression cycle.

3.6.2.4 Sensory evaluation of sweet potato-wheat bread

Sensory evaluation was conducted to assess the quality and consumer acceptance of sweet potato-wheat bread. A total of twenty-one (21) semi-trained panelists participated in the sensory analysis. The panelists were selected based on their familiarity with bread products and were given basic training on sensory analysis techniques, including how to assess key characteristics like aroma, appearance, color, taste, and texture. The training included practice sessions where panelists were introduced to the specific sensory attributes of interest and familiarized with the evaluation process.

The sensory attributes evaluated included overall acceptability, color, appearance, aroma, and taste of the bread. The evaluation was carried out using a 9-point hedonic scale, where panelists rated each attribute based on their degree of liking or disliking. The scale was explained to the panelists as follows: 9 = Like extremely, 8 = Like very much, 7 = Like moderately, 6 = Like slightly, 5 = Neither like nor dislike, 4 = Dislike slightly, 3 = Dislike moderately, 2 = Dislike very much, 1 = Dislike extremely.

Panelists were asked to evaluate each bread sample individually in a controlled environment to minimize bias. They rinsed their mouths between samples to prevent flavor carryover. The sensory data collected were used to assess the acceptability of the different formulations and to identify potential areas for product improvement based on consumer preferences.

3.6.2.5 Proximate composition of sweet potato-wheat bread

3.6.2.5.1 Crude Protein content

Protein Content was determined using Micro Kjeldhal method (AOAC, 2000). The bread sample was ground and 1 g put carefully to a 250ml digestion tube. 1 tablet of Kjeldahl catalyst, and 12ml of conc. H_2SO_4 was added to the sample in the digestion tube, and shaken gently to wet the sample and digested at $410^{\circ}C$ for 1 hour resulting into the content of the digestion tube becoming colorless. The unit then cooled down to $30^{\circ}C$. Onto the the cooled digest added 50 ml dist. H_2O , as diluent and the tube was fixed tightly at its position in the distillation unit. Then 25 ml of H_3BO_3 and 5 drops of Methyl red indicator was added in a conical flask and using the handle for alkali dispensing on the right hand of the distillation unit, 50ml of 40% NaOH solution was then added

to the diluted digest to avoid over reaction. The $\text{H}_3\text{BO}_3 - \text{HN}_3$ solution was titrated with Standard solution of 0.1N HCl. Protein content was calculated as per the formulae below;

$$\text{Total Nitrogen} = \frac{(V_1 - V_0) \times N \times 0.014}{\text{Sample W or Volume}} \times 100 \quad (3.9)$$

$$\% \text{ Protein} = \text{Total Nitrogen} \times K \quad (3.10)$$

Where V_1 = Volume of acid used during titration; V_0 = Volume used for blank titration; N = Normality of HCl acid used = 0.1N; W = Sample weight; Volume. = Sample volume ; K = Correction factor = 6.25

3.6.2.5.2 Crude Fat Content

AOAC, (2000) method was used to calculate the fat content. After being ground, the sample was dried for five hours at 105 °C in the oven. Then 5 g of sample was added into a labeled thimble put in a small beaker and the labeled aluminium cups weighed. A thin layer of cotton wool was placed on top of the sample in the thimble and an adapter inserted on top of cotton wool in thimble. The knobs each side of the unit were raised upwardly and attached to the thimbles and cups fixed. Into a measuring cylinder was added 60ml of petroleum ether and transferred to the cups fixed. A rubber ring was placed on each of the cup and put on above the extraction hot plates then adjusted using the knobs below it, in order to attach each cup under its corresponding thimble. Extraction was performed at 100°C for 15 min. Then, the thimbles were raised out of the solvent and rinsed for 30 min. The Solvent was left to condense and collected above the taps at the base of the condenser until no more solvent was condensing. The compressed air valves were raised on the extraction unit for 15 min to facilitate drying of the thimbles. The unit was then left to cool for 15 min then aluminum cups removed carefully and put in the oven at 105°C for 2 hours to dry. The oven was turned off and it cooled to 40°C with the cups inside. The cups were then removed, and put in the dessicator to cool for 30 minutes. The cups were then weighed to obtain W_3 . Crude fat content was calculated as shown below;

$$\% \text{ Fat} = \frac{W_3 - W_2}{W_1} \times 100 \quad (3.11)$$

Where, W_3 = weight of extraction cup + residue weight (g); W_2 = weight of extraction cup (g); W_1 = original sample weight (g)

3.6.2.5.3 Crude Ash content

Ash content was determined as per the AOAC (2000) method. 3 g of sample was put into a tarred and dry crucible. Crucibles were put in a muffle furnace at 550 °C for 6 hours. The ashed samples in the crucibles were transferred into the dessicator. The crucibles were covered and the dessicator closed to allow cooling prior to weighing. Then crucibles were weighed and the readings recorded.

The ash content was calculated as follows;

$$\% \text{Ash} = \frac{G_2 - G_1}{W} \quad (3.12)$$

Where, G_2 = weight after ashing (sample + crucible); G_1 = Tare weight of crucible; W = Original sample weight

3.6.2.5.4 Crude fibre content

Crude fiber content was analyzed using the AOAC method 978.18 (AOAC, 2006). A total of 4 grams of the defatted sample was placed in a beaker and boiled with 20 ml of a 1.25% H_2SO_4 solution for 30 minutes under reflux. After boiling, the samples were rinsed multiple times with hot water using a two-fold nylon cloth. They were then transferred back to the flask, where 20 ml of a 1.25% NaOH solution was added. The samples were carefully moved into a pre-weighed porcelain crucible and dried in an oven at 105°C for 3 hours. After drying, they were cooled in a desiccator and weighed (W_2). Following this, the samples were incinerated in a muffle furnace at 550°C for 3 hours until they were reduced to ash. The ash was then cooled in a desiccator and weighed again. The crude fiber content was calculated using the following formula:

$$\text{Crude Fibre (\%)} = \frac{W_1 - W_2}{W_0} \times 100 \quad (3.13)$$

W_0 = Sample weigh (g); W_1 = Crucible and residue weight (g); W_2 = Crucible and ash weight (g).

3.6.2.5.5 Moisture content

Moisture content was analysed as per the AOAC method (1999). Clean petri dishes put to dry in an electric oven for 5 hours at 105 °C, then removed and thereafter cooled in a desiccator for 30 minutes. The petri dishes were then weighed. Then 10g of sample was added to the petri-dishes

and placed in the oven at 105°C for 5 hours. The sample was taken out and transferred to the desiccator for 30 min to cooled at ambient temperature and weighed.

Moisture content was calculated according to the expression below;

$$\% \text{ Moisture} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100 \quad (3.14)$$

3.6.2.5.6 Carbohydrate content

The carbohydrate content was determined by calculating the difference between 100 and the sum total of the other proximate components (AOAC, 2005) according to the expression below:

$$\% \text{ CHO} = 100 - \% (\text{Protein} + \text{Fat} + \text{Fibre} + \text{Ash} + \text{Moisture content}) \quad (3.15)$$

3.6.3 Characterization of sweet potato cake

3.6.3.1 Preparation of sweet potato cake

The cake formula used in production of the sweet potato cake was in accordance to methods described by Bennion & Bamford (1997) with some modifications. Sweet potato flour and wheat flour (SP:W) were combined in the ratios of 0:100, 20:80, 30:70 and 60:40. The creaming method was used, where 250 g of sugar and 300 g of fat were mixed and creamed into a Kenwood mixer for 10 minutes until fluffy. 6 liquid eggs were added and mixed for 5 minutes. All dried ingredients including the 500 g of the composite flour, 1.5 g of calcium propionate, 20 g of baking powder were added to form the batter. Milk and water were added gradually until a cake batter was formed. Vanilla essence was also added as a flavoring. The batter mixture was placed into prepared cake pans and cooked for 15 minutes at 190°C. The cakes were removed and cooled for 1hr. The cooled cakes were packed in foam plates and sealed using a wrapping film and kept on shelf until analysis.

3.6.3.2 Texture of the sweet potato-wheat Cake

The texture of cake was analysed using a TVT texture analyzer (TVT 6700). The cupcakes, 100W, OFSP:W 80:20, OFSP: W 70:30, OFSP: W 60:40, WFSP: W 80:20, WFSP: W 70:30 and WFSP: W 60:40 were placed respectively on the measuring stage and centered below the probe. The

starting distance of the probe from the sample was 5mm. Firmness of the cakes was determined by single cycle compression using a 25mm diameter, rounded edge, stainless steel probe, number. 67.30.26. The measurement data was obtained as soon as the probe reached the pre-set trigger force of 20g. The probe compressed the sample to a pre-defined distance of the sample height (6mm compression). The probe then returned to its starting position after the compression cycle.

3.6.3.3 Sensory analysis

3.6.3.4 Sensory properties of the sweet potato-wheat Cake

The sensory attributes of the cake was evaluated by a team of 21 semi-trained panelists using the 9-point hedonic scale. Refer to section 3.5.2.4

3.6.3.5 Proximate analysis of sweet potato-wheat Cake

3.6.3.5.1 Crude Protein Content

Protein Content of the cake was analysed using Micro Kjeldhal method (AOAC, 2000) refer to section 3.6.2.5.1

3.6.3.5.2 Crude Fat Content

The fat content of the cake was analysed as described by (AOAC, 2000) refer to section 3.6.2.5.2

3.6.3.5.3 Crude Ash content

Ash content of the cake was analysed by the method described by Melon & Pomeranz (1980), refer to section 3.6.2.5.3

3.6.3.5.4 Crude Fibre Content

Crude fibre of the cake was analysed according to the AOAC method 978.18 (AOAC, 2006) refer to section 3.6.2.5.4

3.6.3.5.5 Moisture content

The moisture content of the cake was analysed as per the AOAC method (1999), refer to section 3.6.2.5.5

3.6.3.5.6 Carbohydrate content

The carbohydrate content of the cake was determined as per the (AOAC, 2005) method. Refer to section 3.6.2.5.6

3.6.4 Characterization of sweet potato Cookie

3.6.4.1 Preparation of sweet potato cookie

Sweet potato-wheat flour (SP:W) cookies were made in the flour composite ratios of 0: 100, 20 :80, 30 : 70 and 60: 40 were prepared. Wheat and sweet potato flour composites as well as 3 beaten liquid eggs, 200 g of sugar, 15 g baking powder, 3 g Calcium propionate and 300 g fat were weighed using a digital laboratory scale. The powdered components were mixed thoroughly well using a mixer. Then all ingredients including eggs and water were added and all ingredients mixed for about 5 minutes to obtain a soft non-cohesive dough. The dough was spread out using a rolling pin. The dough was then physically shaped into circles using design molds, placed on lightly greased trays, and then put into a preheated oven for 15 minutes at 190°C. The cookies were then placed on foam plates after for about an hour at room temperature before further analysis.

3.6.4.2 Texture of the sweet potato-wheat cookie

The texture of cookie was analysed using a TVT texture analyzer (TVT 6700) by single cycle compression test, AIB Standard Procedure. The cookies; 100W, OFSP:W 80:20, OFSP: W 70:30, OFSP: W 60:40, WFSP: W 80:20, WFSP: W 70:30 and WFSP: W 60:40 were placed respectively on the support plates and centered below the break probe. The starting distance of the probe from the sample was 5mm. Fractuability and hardness of the cookies was determined by single cycle compression using a 70mm diameter, aluminium break probe, number. 67.11.70 with a three point bend rig, part number: 67.50.40. The measurement data was obtained as soon as the probe reached the pre-set trigger force of 20g. The probe compressed the sample to a pre-defined distance of the sample height (15mm compression). The probe then returned to its starting position after the compression cycle.

3.6.4.3 Sensory analysis of sweet potato-wheat cookie

Sensory attributes of the cookie was evaluated by 21 semi-trained panelists using the 9-point hedonic scale. Refer to section 3.6.2.4

3.6.4.4 Proximate analysis of sweet potato-wheat cookie

3.6.4.4.1 Crude Protein content

Protein Content of the cookie was analysed using Micro Kjeldhal method (AOAC, 2000)refer to section 3.6.2.5.1

3.6.4.4.2 Crude Fat Content

The fat content the cookie was analysed as described by (AOAC, 2000) refer to section 3.6.2.5.2

3.6.4.4.3 Crude Ash content

The ash content of the cookie was analysed as per the method described by Melon & Pomeranz (1980), refer to section 3.6.2.5.3

3.6.4.4.4 Crude fibre content

The crude fibre content of the cookie was analysed as per the AOAC method 978.18 (AOAC, 2006) refer to section 3.6.2.5.4

3.6.4.4.5 Moisture content

The moisture content of the cookie was analysed as per the AOAC method (1999), refer to section 3.6.2.5.5

3.6.4.4.6 Carbohydrate content

Carbohydrate content of the cookie was analysed as per (AOAC, 2005) method. Refer to section 3.6.2.5.6

3.6.5 Characterization of sweet potato meal and porridge

3.6.5.1 Meal

3.6.5.1.1 Preparation of sweet potato meal

The eggs were broken into a weighed bowl. The weight of the eggs was also taken and then whisked before being poured onto a stainless-steel tray to be dried. The eggs were put in the oven first at 90°C to allow coagulation while breaking the surface scum. After coagulation, the temperature was then reduced to 60°C and the eggs allowed to dry 36 hours while constantly turning them to ensure thorough drying. After drying, the eggs were removed and collected in a plastic bag and weighed to obtain the yield. The eggs were then milled using a heavy-duty blender to obtain the egg powder. Similarly, silverfish was sorted carefully to get out stones and any foreign materials, beheaded to avoid bitterness and then dipped in water (washed) and turned in order to remove any dust. The silverfish was drained and dried in the oven at 60°C for 24 hours. It was then milled into a powder using a heavy-duty blender. The sweet potato flour previously prepared was used to formulate a sweet potato fish and egg meal.

A composite flour containing sweet potato flour, silver fish and egg powders (S: F: E = 74: 7: 19) was formulated to which 1% salt was added. A spice powder from onions, turmeric and cadamon prepared and added at a rate 2%. The resulting composite was prepared for extrusion by taking 7 kg of the composite flour and adjusting moisture content to about 14% by adding 500 ml of water and mixed in MACADAMS mixer (model SM-201S) for 7 minutes at room temperature to allow even distribution of the moisture until a cohesive mass was formed when pressed in the palms. The composite mixture was transferred to the extruder (model Js-60D, China) set at 60°C/120°C initial processing temperature and 140°C as extrusion temperature. The other extrusion conditions were: feeding rate of 10.15 kg/hr, screw speed of 30 rpm and barrel temperature of 80°C. Before extrusion, the extruder was cleaned by extruding flour mixtures treated in the same way and extruded at 140°C. Then, the composite mixture was extruded using same rotating twin screw extruder with L/D ratio of 16:1 and screw diameter of 60 mm ((model Js-60D, China) under the above conditions with the extrusion temperature at 140°C. The noodle extrudates were collected and allowed to cool and dry in the open air. The cool dry noodles were then milled into a fine flour. The fine composite flour (powder) was finally packed into 300 g units using pre-formed closable

plastic pouches and sealed immediately to avoid further moisture absorption. The composite powders were kept for further chemical and sensory analysis.

3.6.5.1.2 Sensory analysis of sweet potato meal

Sensory attributes of the meal were evaluated by 21 semi trained panelists using the 9–point hedonic scale. Refer to section 3.6.2.4

3.6.5.1.3 Proximate analysis of sweet potato meal

3.6.5.1.3.1 Crude Protein content

Protein Content of the meal was analysed as per the Micro Kjeldhal method (AOAC, 2000) refer to section 3.6.2.5.1

3.6.5.1.3.2 Crude Fat Content

The fat content of the meal was analysed as per procedure described by (AOAC, 2000) refer to section 3.6.2.5.2

3.6.5.1.3.3 Crude Ash Content

Ash content was analysed by method outlined by Melon & Pomeranz (1980), refer to section 3.6.2.5.3

3.6.5.1.3.4 Crude Fibre Content

Crude fibre was analysed according to the AOAC method 978.18 (AOAC, 2006 refer to section 3.6.2.5.4

3.6.5.1.3.5 Moisture content

Moisture content of the meal was determined according to the AOAC method (1999), refer to section 3.6.2.5.5

3.6.5.1.3.6 Carbohydrate content

The carbohydrate content of the meal was analysed as per the (AOAC, 2005) method. Refer to section 3.6.2.5.6

3.6.5.2 Porridge

3.6.5.2.1 Preparation of sweet potato porridge

The silver fish was prepared as in section 3.6.5.1.1. Lato milk powder was purchased from the market. The composite flour was formulated according to the ratios Sweet potato:Fish:Milk (70: 10 : 20). The formulated composite flour was prepared for extrusion using the same conditions including subsequent treatments as for the meal (section 3.5.5.1.1). The extruded and milled composite powders were bagged in 300 g units, sealed and stored for further chemical and sensory analysis.

3.6.5.2.2 Sensory analysis of sweet potato porridge

Sensory attributes of the porridge were evaluated by 21 semi trained panelists using the 9–point hedonic scale. Refer to section 3.6.2.4

3.6.5.2.3 Proximate analysis of sweet potato porridge

3.6.5.2.3.1 Crude protein content

Protein Content of the porridge was analysed using Micro Kjeldhal method (AOAC, 2000) refer to section 3.6.2.5.1

3.6.5.2.3.2 Crude fat content

The fat content of the porridge was analysed as per procedure described by (AOAC, 2000) refer to section 3.6.2.5.2

3.6.5.2.3.3 Crude Ash content

Ash content of the porridge was analysed as per procedure described by Melon & Pomeranz (1980), refer to section 3.6.2.5.3

3.6.5.2.3.4 Crude fibre content

Crude fibre content of the porridge was determined according to the AOAC method 978.18 (AOAC, 2006) refer to section 3.6.2.5.4

3.6.5.2.3.5 Moisture content

Moisture content of the porridge was analysed according to the AOAC method (1999), refer to section 3.6.2.5.5

3.6.5.2.3.6 Carbohydrate content

Carbohydrate content of the porridge was analysed as per (AOAC, 2005) method. Refer to section 3.6.2.5.6.

3.7 Statistical analysis

The data was analyzed using Excel stat package version 10 and Statistical Analysis in Social Science (SPSS) version 24 with separation of means by group and analyzed using the one-way Analysis of Variance (ANOVA) with Fisher's Least Significant Difference (LSD), Tukey's post hoc multiple comparison test, and paired comparison tests. Means were tested for homogeneity of variance and significant differences were determined at $P < 0.05$. Correlation analysis was used to measure the associations between selected attributes of sweet potato varieties. The correlation coefficient was used to determine the magnitude and nature of the correlation. A negative coefficient meant a negative relationship between the variables. Associations or correlations were considered significant if the corresponding p-values were less or equal to 0.05. To assess differences between local and hybrid varieties, the independent t-test was used since there were only two independent varieties. Mean differences were significant at the 5% level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Skin & Pulp Color and Chemical Characteristics of the Selected Local and Hybrid Sweet Potato Varieties

4.1.1 Skin and Pulp Color

The skin and pulp color results for the ten sweet potato varieties are summarized in Table 4.1.

Both local and hybrid sweet potato varieties exhibited either cream or purple skin, while pulp colors varied between yellow, white, and orange, depending on the variety. There was no direct correlation between skin and pulp color.

Table 4. 1: Skin and pulp color of the ten (10) local and hybrid sweet potato varieties

Sweet potato variety	Skin color	Pulp color
<i>Nakakande</i>	Purple	Yellow
<i>Mubalira Bbali</i>	Cream	Yellow
<i>Sukali</i>	Cream	White
Narospot 1	Purple red	light cream
<i>Njule</i>	Cream	White
<i>Kasanda</i>	Purple	White
<i>New Kawogo</i>	Purple	Yellow
Naspot 8	Purple red	Light Orange
Naspot 12	Purple red	Light Orange
Naspot 13	Cream	Deep Orange

These results are in line with the findings of Gisele & Koua (2018), who similarly reported that color is mainly dependent on the variety. Mwanga *et al.* (2016), who noted that Naspot 12 had purple-red skin and Naspot 13 had cream-colored skin, with both showing deep orange flesh. They concluded that the intensity of these colors varied based on factors such as location, the age of the roots, and agro-climatic conditions. According to Gisele & Koua (2018), hybrid varieties tended to have orange-fleshed roots, whereas local varieties displayed yellow and white flesh. Similarly, Abongo, Omayio, & Okoth (2016) reported that Ugandan sweet potato varieties are differentiated by their color and shape, with flesh color varying according to carotenoid content.

The pigments responsible for sweet potato color include anthocyanidins, which contribute to red or purple skin, β -carotene, which gives dark yellow or orange flesh, and flavonoids, which provide a yellow hue (Yayuan, Cai, & Xu, 2015). Both Gisele & Koua (2018) and Jenkins, Shanks, & Bailey (2015) found a correlation between β -carotene values and the intensity of sweet potato flesh color. In general, the orange-fleshed varieties of sweet potatoes contain significantly higher amounts of β -carotene compared to white fleshed ones (Adeyemi & Salaam, 2015).

In conclusion, the findings from this study indicate significant variation in both skin and pulp color among the selected local and hybrid sweet potato varieties. The lack of a direct correlation between skin and pulp color suggests that these traits are independently controlled, influenced by a combination of genetic and environmental factors. Furthermore, the higher β -carotene content in orange-fleshed varieties underscores their potential nutritional value, especially in regions where vitamin A deficiency is a concern.

4.1.2 pH of the Sweet Potato Varieties

The pH values of the various sweet potato varieties in this study ranged significantly from 6.42 to 7.60 (Table 4.2). Specifically, *Kasanda* had the lowest pH at 6.42, while *Nakakande* exhibited the highest pH value of 7.60. These pH values are consistent with previously reported ranges for sweet potatoes, which have been found to vary between 5.04 and 7.26 (Solomon *et al.*, 2015). The pH range observed in this study also aligns with the findings of Kure-Nwankwo and Wiyasu (2012), who reported similar pH values for various sweet potato cultivars.

The pH of sweet potatoes can influence the flavor, texture, and storage potential of the crop, and is influenced by a variety of factors including cultivar, growing conditions, and post-harvest handling (Kure-Nwankwo & Wiyasu, 2012). *Kasanda's* lower pH (6.42) suggests it may have slightly more acidic properties compared to other varieties, which could potentially impact its processing and consumption characteristics. On the other hand, *Nakakande's* higher pH (7.60) reflects a more neutral or alkaline nature, which could be related to variations in soil composition or nutrient uptake during cultivation (Solomon *et al.*, 2015).

Table 4. 2. pH, dry matter, beta-carotene, polyphenol content, and sugar of selected local and hybrid sweet potato varieties

Variety	PH	% Dry matter	Beta carotene ($\mu\text{g}/100\text{ g}$)	Polyphenol (GAE mg/100g)	Sugar (mg/g)
<i>Kasanda</i>	6.42 ^g	38.8 ^{ab}	1465 ^c	0.554 ^a	3.390 ^b
<i>Mubalira Bbali</i>	7.35 ^{bcd}	34.9 ^{ab}	967 ^{de}	0.232 ^e	2.300 ^f
<i>Nakakande</i>	7.60 ^a	29.5 ^b	1068 ^d	0.219 ^e	2.269 ^f
Narospot 1	7.08 ^e	34.9 ^{ab}	948 ^{de}	0.200 ^f	1.887 ^g
Naspot 12	7.35 ^{cd}	40.3 ^{ab}	2819 ^b	0.511 ^b	2.535 ^d
Naspot 13	6.86 ^f	33.1 ^{ab}	6556 ^a	0.205 ^f	2.425 ^e
Naspot 8	7.51 ^{ab}	34.0 ^{ab}	2785 ^b	0.178 ^g	2.788 ^c
New <i>Kawogo</i>	7.50 ^{abc}	42.8 ^a	793 ^{ef}	0.456 ^c	2.387 ^e
<i>Njule</i>	7.25 ^d	34.2 ^{ab}	715 ^f	0.312 ^d	3.964 ^a
<i>Sukali</i>	7.40 ^{bcd}	34.2 ^{ab}	648 ^f	0.229 ^e	2.555 ^d

Values along the same column with the same superscript are not significantly different.
GAE = Garlic Acid Equivalent

The pH level is also known to affect the bioavailability of certain nutrients and the stability of storage compounds such as starches and sugars in sweet potatoes (Nguyen et al., 2021). For instance, sweet potatoes with lower pH may have improved storage qualities, especially in terms of shelf life and resistance to post-harvest spoilage. This is particularly important in regions with limited refrigeration or storage facilities (Kure-Nwankwo & Wiyasu, 2012).

Furthermore, the pH of sweet potatoes has been shown to influence the formation of anthocyanins, which are responsible for pigmentation in certain varieties, and can affect the antioxidant activity of the tubers (Wang et al., 2017). Although pH did not show a direct correlation with pigment concentration in this study, previous research suggests that slightly more acidic conditions might support better retention of anthocyanin content, as seen in red-skinned sweet potatoes (Nong et al., 2020).

Overall, the pH values observed in this study are within the typical range for sweet potatoes, and these variations may have implications for the crop's culinary, nutritional, and storage properties. Further research could examine the interactions between pH and other chemical characteristics,

such as polyphenol content and starch formation, to better understand how pH influences the overall quality of sweet potato varieties.

4.1.3 Dry Matter Content

The dry matter content of the selected sweet potato cultivars varied significantly, ranging from 29.5% to 42.8% (Table 4.2). *New Kawogo* exhibited the highest dry matter content at 42.8%, while *Nakakande* had the lowest at 29.5%. Although this variation in dry matter content across the varieties was statistically significant, no significant differences were found when comparing the dry matter content between the varieties. This variability can likely be attributed to multiple factors, including cultivar type, soil quality, irrigation practices, and climatic conditions, all of which are known to impact the physiological development of sweet potatoes (Ssemakula, 2014; Tsegay *et al.*, 2021).

The dry matter content observed in this study is consistent with findings from previous research. For instance, Aweke & Baruch (2016) reported dry matter values ranging from 25.09% to 46.12% across various sweet potato cultivars in different regions. Similarly, Ellong, Billard, & Adenet (2014) found dry matter content ranging from 29.56% to 39.32% in sweet potatoes cultivated in Martinique. Laurie, Van Jaarsveld, Faber, & Labuschagne (2012) also reported dry matter values between 18.5% and 30.5% for a range of sweet potato varieties grown under diverse conditions. These findings further confirm that dry matter content can vary widely across different cultivars and environmental conditions, underscoring the importance of local factors such as soil health, water availability, and temperature in influencing these levels.

High dry matter content is closely associated with improved cooking quality, as it enhances texture and consistency during cooking. It also contributes to the extended storage periods of the tubers, making them less prone to microbial spoilage (Eleazu & Ironua, 2015). Furthermore, tubers with higher dry matter content are generally preferred in the processing industry because they yield higher-quality products, such as flour and starch, due to their better consistency and higher yield per unit of raw material (Megnanou *et al.*, 2009). Sweet potatoes with elevated dry matter content are also known for their improved texture in processed foods such as chips, fries, and other baked goods (Montagnac *et al.*, 2010).

These findings are particularly relevant for the Ugandan sweet potato varieties, as they suggest that the cultivars studied possess favorable dry matter content for culinary and commercial applications. The high dry matter levels observed in *New Kawogo* in particular, position it as a promising candidate for processing into value-added products like flour, starch, and snacks. The variation in dry matter content among the varieties also indicates the importance of selecting appropriate cultivars for specific processing or cooking needs.

Overall, the presence of high dry matter levels in certain varieties, such as *New Kawogo*, indicates the potential for use in commercial processing, where dry matter content is critical for yield and product quality

4.1.4 Beta-Carotene Content

The beta-carotene levels in the sweet potato varieties studied ranged from 6.48 to 65.56 $\mu\text{g/g}$, with hybrid varieties generally exhibiting higher concentrations than local varieties (Table 4.2). Notably, Naspot 13, an orange-fleshed variety, had the highest beta-carotene content, while *Kasanda*, a white-fleshed variety, had the lowest. In general, the beta-carotene levels in the hybrid varieties (with the exception of Narospot 1) were significantly higher than those in the local varieties. These results indicate a clear correlation between beta-carotene content and the intensity of the flesh color, with orange-fleshed varieties consistently displaying higher beta-carotene concentrations compared to yellow- and white-fleshed varieties.

This finding is consistent with previous studies that have highlighted the positive relationship between the color intensity of sweet potato flesh and its beta-carotene content. Jenkins et al. (2015) observed that an increase in flesh color intensity, particularly from yellow to orange, is closely associated with a higher beta-carotene concentration in sweet potatoes. In line with this, Tumwegamire *et al.* (2014) and Kambale (2017) also reported that Naspot 13 had the highest beta-carotene content among the sweet potato varieties they evaluated, particularly among orange-fleshed cultivars. Furthermore, the presence of high beta-carotene in these varieties is highly significant, as it directly contributes to their nutritional value, particularly in addressing vitamin A deficiency, which is a major public health concern in many parts of the world, including Uganda (Low *et al.*, 2020).

The beta-carotene content of sweet potatoes is influenced by several factors, including variety, maturity, and environmental growth conditions. The variations in beta-carotene levels observed in this study may be attributed to these factors, which can differ based on geographical regions and specific agricultural practices (Low *et al.*, 2020). The sweet potatoes in this study were harvested at 3 to 4 months after planting, depending on the variety. The timing of harvest is critical, as beta-carotene levels are known to fluctuate with the stage of maturity, with some varieties showing higher concentrations closer to physiological maturity (Nwosu *et al.*, 2019). Additionally, factors such as soil nutrient availability, irrigation practices, and the use of organic amendments can also play a role in determining beta-carotene content (Haug *et al.*, 2020).

In terms of practical implications, the high beta-carotene levels found in hybrid varieties like Naspot 13 emphasize their potential role in improving dietary vitamin A intake, particularly in regions where deficiencies are widespread. These findings suggest that farmers growing these orange-fleshed hybrids could contribute to improving the nutritional quality of their produce, thereby enhancing food security and public health outcomes in Uganda and other regions with similar dietary challenges.

In conclusion, the beta-carotene content of the evaluated sweet potato varieties demonstrates a strong link between flesh color and nutrient density, with orange-fleshed varieties such as Naspot 13 showing the highest levels of beta-carotene. This study reinforces the nutritional importance of sweet potato varieties with high beta-carotene content, particularly in addressing vitamin A deficiency. The variation in beta-carotene levels across the different varieties highlights the importance of selecting appropriate cultivars for specific health and culinary needs

4.1.5 Polyphenol Content

The total polyphenol content (TPC) of the selected sweet potato varieties varied significantly, ranging from 0.178 to 0.554 mg GAE/g (wet basis), as shown in Table 4.2. *Kasanda* exhibited the highest polyphenol content at 0.554 mg/g, followed by *Naspot 12* (0.511 mg/g), *New Kawogo* (0.456 mg/g), and *Njule* (0.312 mg/g). In contrast, *Naspot 13* (0.205 mg/g), *Narospot 1* (0.200 mg/g), and *Naspot 8* (0.178 mg/g) displayed the lowest polyphenolic content. These results indicate considerable variation in polyphenol content among both local and hybrid sweet potato

varieties. Notably, the polyphenol content in yellow and white-fleshed cultivars generally surpassed that of the orange-fleshed varieties.

This trend is consistent with the findings of Frankova *et al.* (2022), who reported that the TPC in raw, untreated sweet potatoes ranged from 0.157 to 0.623 mg GAE/g, and that flesh color played a key role in determining the polyphenol content. Specifically, varieties with yellow and white flesh tended to have higher polyphenol concentrations, supporting the findings of this study. Additionally, the TPC of orange-fleshed sweet potato varieties aligns with the results of Kona and Baratova (2011), who reported a TPC of 0.472 mg/g fresh weight for orange-fleshed cultivars.

The elevated TPC in *Kasanda*, *New Kawogo*, and Naspot 12 is attributed to their higher sap content, as suggested by previous studies. Research by Anyanga (2015) found that sweet potato varieties with higher sap content typically have elevated TPC values, which is consistent with the results of this study. In particular, *New Kawogo* exhibited a high TPC, likely due to its root latex content, which surpasses that of varieties such as NaroSpot 1. NaroSpot 1 has a higher concentration of hexadecylcaffeic acid and octadecylcaffeic acid, compounds associated with lower polyphenol content (Amoah *et al.*, 2014).

Furthermore, the degree of browning in peeled sweet potatoes is significantly correlated with phenolic content. As such, varieties like *Kasanda*, *New Kawogo*, and Naspot 12—which have higher polyphenol levels may be more prone to browning during processing. To mitigate this, treatments such as blanching, sulfiting, ascorbic acid, or citric acid could be applied to reduce browning and improve the appearance of these varieties during processing (Amoah *et al.*, 2014).

These findings suggest that the polyphenol content of sweet potatoes is influenced by several factors, including flesh color, sap content, and the presence of specific phenolic acids. Polyphenols are important antioxidants and contribute to the nutritional and health benefits of sweet potatoes. Therefore, varieties with higher TPC could offer greater potential for improving dietary intake of phenolic compounds, which have been linked to a range of health benefits, including antioxidant activity and the prevention of chronic diseases (Wang *et al.*, 2020).

In conclusion, this study demonstrates significant variation in the polyphenol content of sweet potato varieties, with yellow and white-fleshed varieties generally exhibiting higher TPC than orange-fleshed varieties. The findings highlight the importance of sap content and phenolic acids

in determining polyphenol levels. Additionally, the higher polyphenol content in certain varieties suggests potential applications in food processing, where minimizing browning during storage and preparation is important. Further research into processing techniques and the impact of different treatments on polyphenol retention could help improve the overall quality and consumer acceptance of sweet potatoes with higher TPC.

4.1.6 Crude Protein Content

Crude protein content of the selected varieties of sweet potatoes exhibited significant variation, with Naspot 8 (4.77%) and *Mubalira Bbali* (1.79%) having the highest and lowest crude protein content, respectively (Table 4.3). This range is comparatively higher than that of other roots and tubers, such as cassava, but lower than that of Irish potatoes. Similar protein contents in sweet potatoes have been reported by other studies. For instance, Villareal et al. (2008) reported a protein content of approximately 2.8%, while Senanayake et al. (2013) found protein content ranging from 1.2% to 3.3%. In general, the protein content observed in this study is comparable to that of other sweet potato cultivars from different regions of the globe (Mohammad *et al.*, 2016).

Table 4.3: Crude Protein Content (%) of the selected local and hybrid sweet potato varieties.

Variety	Protein	Crude Fat	Crude Fibre	Moisture	Ash	Total Carbohydrate
<i>Kasanda</i>	3.42 ^e	5.00 ^a	2.77 ^{ab}	61.2 ^{ab}	0.98 ^a	26.63 ^d
<i>Mubalira Bbali</i>	1.79 ^g	2.33 ^a	2.22 ^b	65.1 ^{ab}	1.05 ^a	27.51 ^b
<i>Nakakande</i>	2.84 ^f	2.17 ^a	3.67 ^{ab}	70.5 ^b	0.25 ^a	20.57 ⁱ
Narospot 1	3.45 ^e	1.67 ^a	3.17 ^{ab}	65.1 ^{ab}	1.54 ^a	25.07 ^f
Naspot 12	3.48 ^{de}	5.50 ^a	3.17 ^{ab}	59.7 ^{ab}	1.02 ^a	27.13 ^c
Naspot 13	3.53 ^d	2.17 ^a	3.40 ^{ab}	66.9 ^{ab}	1.67 ^a	22.33 ^g
Naspot 8	4.77 ^a	1.83 ^a	4.50 ^a	66.0 ^{ab}	0.54 ^a	22.36 ^g
<i>New Kawogo</i>	4.10 ^b	3.17 ^a	2.67 ^{ab}	57.2 ^a	0.65 ^a	32.21 ^a
<i>Njule</i>	3.77 ^c	2.67 ^a	4.47 ^a	65.8 ^{ab}	1.48 ^a	21.81 ^h
<i>Sukali</i>	2.80 ^f	2.33 ^a	2.26 ^b	65.8 ^{ab}	1.00 ^a	25.81 ^e

Values along the same column with the same superscript are not significantly different. (P < 0.05).

The variation in protein content among the varieties can be attributed to multiple factors such as genetic differences, environmental conditions, and agronomic practices. Higher protein content in Naspot 8 may be linked to its higher nitrogen uptake and efficient use of nutrients (Bai *et al.*, 2020), whereas *Mubalira Bbali* showed lower protein content, which may be influenced by its adaptation to specific agro-ecological conditions (Rashid *et al.*, 2014). Additionally, the observed protein content in this study suggests that sweet potatoes can contribute to the dietary protein needs of populations that rely heavily on plant-based diets.

4.1.7 Crude Fat Content

The fat content across the different sweet potato varieties varied from 1.67% to 5.50% (Table 4.3). No significant differences were observed among the varieties, with Naspot 12 and *Kasanda* exhibiting higher fat levels compared to others. Generally, sweet potatoes are recognized for their low-fat content. Mohammad *et al.* (2016) reported a fat content of only 0.63%, which is much lower than the fat content reported in this study. Fat plays an important role in food as it contributes to both the structural and biological functions of cells, significantly impacting the energy value of foods (Eleazu & Ironua, 2015). Higher fat levels in Naspot 12 and *Kasanda* may also reflect their greater energy density, which is an important consideration for sweet potato-based diets.

4.1.8 Crude Fiber Content

The crude fiber content of the sweet potatoes ranged from 2.22% to 4.50%, with *Mubalira Bbali* and Naspot 8 having the lowest and highest fiber content, respectively (Table 4.3). Mohammad *et al.* (2016) reported fiber content in sweet potatoes to be between 0.3% and 0.5%. The FAO (2001) documented fiber content of 1.2%. The higher fiber content observed in this study could be due to several factors, such as the region of cultivation, variety, or genetic differences. The increased fiber content in Ugandan sweet potatoes supports their potential as a source of dietary fiber, which is known to aid in digestion and maintain gut health (Nanditha *et al.*, 2020).

4.1.9 Moisture Content

The moisture content (on a wet basis) of the sweet potatoes ranged from 57.2% to 70.5% (Table 4.3). The observed variation in moisture content can be attributed to differences in genetics (Alam, 2016). Wenkam (1983) reported a moisture content of 77.8% for fresh sweet potatoes, while Ingabire & Vasanthakalam (2011) reported moisture content in Rwandan sweet potatoes to be between 62.5% and 64.3%. Moisture content significantly influences the texture and dry matter

content, which in turn affects the qualitative attributes of sweet potato products. Higher moisture content, such as in *Nakakande* (70.5%), can improve the sensory quality of fresh products but may limit shelf life during storage and processing (Dong *et al.*, 2019)

4.1.10 Ash Content

The ash content among the selected sweet potato tubers ranged from 0.25% to 1.67%. No significant differences were observed in ash content among the various sweet potato varieties (Table 4.3). Nwajinka *et al.* (2020) reported ash content in sweet potatoes ranging from 2.0% to 6.2%, while Mohammad *et al.* (2016) reported ash content for fresh sweet potato tubers to be between 1.17% and 1.31%. The differences in ash content reported across various sweet potato studies could be attributed to differences in the mineral content of the soils and fertilizer applications used in cultivation (Karanja *et al.*, 2021).

4.1.11 Crude Carbohydrate Content

Carbohydrate content varied from 20.57% to 32.21%, with *Nakakande* exhibiting the lowest and *New Kawogo* the highest levels (Table 4.3). Among the hybrids, Naspot 13 and Naspot 8 had the lowest carbohydrate content, followed by *Naspot 1* (25.07%) and Naspot 12 (27.13%). Mohammad *et al.* (2016) reported carbohydrate content in sweet potatoes to range from 21% to 25%. According to Alam (2021), carbohydrate content in sweet potatoes varies between 20% and 30%, which is consistent with the findings of this study. Carbohydrate content is influenced by variety, growth conditions, and maturity (Zhou *et al.*, 2021). Sweet potatoes are an excellent source of complex carbohydrates, which provide a sustained release of energy, making them a staple in many diets worldwide.

4.1.12 Total Sugar Content

The sugar content ranged from 1.89 mg/g to 3.96 mg/g, with *Njule* having the highest and *Narospot 1* the lowest sugar levels as seen in Table 4.2. Ingabire & Vasanthakalam (2011) reported lower sugar content in sweet potatoes, ranging from 1.74% to 2.50%. Adebisola *et al.* (2012) noted reducing sugar content between 0.3% and 2.3%, while Moreno-Ochoa *et al.* (2023) found reducing sugar levels ranging from 1.8% to 4.7%. Sucrose is the predominant sugar in raw sweet potatoes, with smaller amounts of glucose and fructose present (Bouwkamp, 1985). The sugar content observed in this study aligns with findings from other studies. Variations in reducing sugar content among different varieties can be attributed to factors such as variety, soil type, cultivation

practices, and genetic differences. Additionally, the timing of harvest can significantly affect total sugar content (Burri, 2011), as well as the duration between harvest and analysis.

In summary, the proximate composition of the selected sweet potato varieties showed significant variation. Crude protein ranged from 1.79% (*Mubalira Bbali*) to 4.77% (*Naspot 8*), and crude fat varied from 1.67% to 5.50%, with *Naspot 12* and *Kasanda* having higher levels. Crude fiber ranged from 2.22% to 4.50%, with *Mubalira Bbali* having the lowest. Moisture content ranged from 57.2% to 70.5%, influencing the texture and shelf life of products. Carbohydrate content varied from 20.57% to 32.21%, with *New Kawogo* having the highest, while total sugars varied from 1.89 mg/g to 3.96 mg/g, with *Njule* showing the highest sugar content.

Therefore, the proximate composition of sweet potato varieties varies significantly in terms of protein, fat, fiber, and carbohydrates, with *Naspot 8* being rich in protein and fiber. Sweet potatoes are a valuable source of carbohydrates and dietary fiber, supporting their potential in energy-dense and nutritious food products. Understanding the nutritional profiles of different varieties can help guide their use in food applications, offering health benefits such as improved digestive health and sustained energy release.

4.2 Physico-Chemical Characterization of Starch Extracted from selected Ugandan Local and Hybrid Sweet Potato Varieties.

4.2.1 Starch Yield

The starch yield (on a wet basis) across the various sweet potato varieties ranged from 15.5% to 29.6% (Table 4.4).

Table 4.4: Percentage of starch yield from local and hybrid sweet potato varieties

Variety	Starch Yield (%) on a wet basis
<i>Sukali</i>	29.6 ± 0.6 ^a
<i>New Kawogo</i>	26.5±2.9 ^{ab}
<i>Mubalila bbali</i>	26.1± 0.4 ^{abc}
<i>Njule</i>	26.0±2.3 ^{abc}
<i>Nakakande</i>	24.7±2.2 ^{abcd}
<i>Kasanda</i>	23.5±3.3 ^{bcd}
Narospot 1	22.5±0.9 ^{bcd}
Naspot 12	20.7± 1.1 ^{cde}
Naspot 8	20.1± 1.2 ^{de}
Naspot 13	15.5± 1.3 ^e

Values along the same column with the same superscript are not significantly different (P < 0.05).

The results indicated that local varieties exhibited the highest starch yields, varying between 23.5% and 29.6%, with *Sukali* achieving the highest yield and *Kasanda* the lowest. In contrast, hybrid varieties demonstrated lower starch content, ranging from 15.5% to 22.5%, with Naspot 13 producing the lowest yield and Narospot 1 the highest among hybrids. Notably, the starch yield from Naspot 13 was significantly lower than that of the local varieties. Overall, certain varieties are better at accumulating starch reserves compared to others, a phenomenon also observed in bananas (Fontes et al., 2017). These variations may influence their processing qualities and sensory attributes, particularly texture. Starch has been linked to the firmness of foods, especially during retrogradation (Gafuma, Mugampoza, & Byarugaba-Bazirake, 2018).

4.2.1 Water Holding Capacity

The water holding capacity (WHC) showed no significant differences among the various sweet potato varieties, ranging from 0.80 to 1.20 g/g as seen on Table 4.5. Starch derived from Nakakande exhibited the highest WHC, while *Sukali* had the lowest.

Table 4.5: Water Holding Capacity of starch extracted from the different sweet potato varieties.

Variety	WHC (g/g)
<i>Nakakande</i>	1.20 ^d
<i>Mbalila bbali</i>	0.95 ^b
<i>Sukaali</i>	0.80 ^c
<i>Kasanda</i>	0.87 ^c
Narospot 1	0.85 ^a
<i>New Kawogo</i>	1.01 ^d
Naspot 8	0.81 ^d
Naspot 12	0.83 ^d
Naspot 13	0.81 ^d
<i>Njule</i>	0.94 ^d

Values along the same column with the same superscript are not significantly different. (P < 0.05).

The slight variations in WHC among the starches from different varieties may be attributed to differences in granular structure and the loose association of amylose and amylopectin molecules (Soni & Sharma, 1989). The degree of availability of water-binding sites also contributes to the differences in WHC across various starch types. Water holding capacity refers to a product's ability

to retain water, which is a key functional property in food (Niba, Niba, Bokonga, Jackson, & Schlimme, 2001). Functional characteristics of starch, such as viscosity—an important measure of water-holding capacity—impact the consistency and bulking of a product (Iheagwara, 2013). Additionally, it helps stabilize starches against syneresis during processes like retorting and freezing, which is essential for the texture of certain foods (Ransford *et al.*, 2014).

4.2.3 Swelling Power and Solubility

4.2.3.1 Swelling power

Swelling power and solubility illustrate the strength of interactions among starch chains within the amorphous and crystalline regions (Hardeep, Paras, Haprabhdeep, & Jaspreet, 2013). The swelling power ranged from 2.04 to 16.07 g/g across a temperature spectrum of 40 to 90°C (Table 4.6). Starch derived from Naspot 13 exhibited the highest swelling power at 90°C (16.072 g/g), while the lowest was recorded in *Mbalila Bbali* at 13.102 g/g.

Table 4. 6: Swelling Power of the Starch over a temperature range of 40°C to 90°C.

Variety	40°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C	90°C
<i>Nakakande</i>	2.04 ^a	2.22 ^a	2.20 ^{ab}	2.40 ^a	5.79 ^b	10.32 ^a	11.86 ^a	12.45 ^{ab}	13.79 ^a	13.63 ^a
<i>Mbalila bbali</i>	2.11 ^a	2.20 ^a	2.17 ^{ab}	2.48 ^a	4.05 ^c	8.46 ^{bcd}	10.46 ^{abc}	10.77 ^{abc}	12.08 ^a	13.10 ^a
<i>Sukaali</i>	2.27 ^a	2.18 ^a	2.10 ^b	2.19 ^a	3.24 ^d	8.74 ^{bcd}	10.88 ^{ab}	10.70 ^{abc}	13.39 ^a	14.02 ^a
<i>Kasanda</i>	2.32 ^a	2.14 ^a	2.23 ^{ab}	2.18 ^a	3.19 ^{de}	8.31 ^{cd}	9.60 ^{bcd}	9.50 ^{bc}	13.15 ^a	13.96 ^a
Narospot 1	2.31 ^a	2.31 ^a	2.20 ^{ab}	2.25 ^a	2.97 ^{de}	8.28 ^{cd}	9.70 ^{bcd}	8.89 ^c	12.41 ^a	13.38 ^a
<i>New Kawogo</i>	2.25 ^a	2.34 ^a	2.39 ^a	2.46 ^a	2.97 ^{de}	7.76 ^d	8.33 ^d	9.04 ^c	12.26 ^a	11.57 ^a
Naspot 8	2.20 ^a	2.20 ^a	2.10 ^b	2.51 ^a	5.84 ^b	9.49 ^{abc}	11.90 ^a	12.43 ^{ab}	14.65 ^a	15.69 ^a
Naspot 12	2.19 ^a	2.21 ^a	2.17 ^{ab}	3.25 ^a	5.29 ^b	9.68 ^{ab}	11.39 ^{ab}	11.70 ^{abc}	13.60 ^a	16.04 ^a
Naspot 13	2.17 ^a	2.12 ^a	2.21 ^{ab}	2.99 ^a	7.00 ^a	10.18 ^a	11.94 ^a	12.94 ^a	15.40 ^a	16.07 ^a
<i>Njule</i>	2.20 ^a	2.27 ^a	2.10 ^b	2.30 ^a	2.61 ^e	8.00 ^d	8.79 ^{cd}	10.80 ^{abc}	12.51 ^a	14.03 ^a

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

There was a notable increase in swelling power of the sweet potato starch with rising treatment temperatures. Between 40 and 60°C, swelling power remained relatively consistent across the varieties. However, significant variations were observed between 65 and 80°C, while no

substantial changes in swelling power occurred above 85°C. According to Eke-Ejiofor and Mbaka (2018), swelling power indicates the extent to which starch expands in relation to its original volume.

Akinwale, Niniola, & Abass (2017) and Demiate & Kotovicz (2011) noted a two-stage swelling phenomenon in starches, aligning with these findings. The observed reduction in swelling power at higher temperatures suggests increased solubilization of starch molecules. Starch granules reach their peak swelling point, after which they begin to disintegrate, releasing soluble components such as amylose (Shadrack, Tilahum, Geremew, & Mark, 2019). Consequently, the temperature range of 85–90°C exhibited a decline in the rate of swelling power increase alongside a rise in solubility.

4.2.3.2 Solubility

The alterations in the solubility of starch mirrored the trends observed in swelling power and it varied significantly, ranging from 0.333% to 10.833% across different temperatures. Naspot 13 exhibited the highest solubility at 90°C (10.833%), while the lowest was recorded in Narospot 1 at 6% (Table 4.7).

Table 4. 7: Solubilities of the Starches extracted from Ugandan local and hybrid sweet potato varieties.

Variety	40°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C	90°C
<i>Nakakande</i>	0.83 ^{bc}	0.67 ^b	1.00 ^b	0.33 ^c	2.33 ^a	2.50 ^{ab}	4.17 ^{bc}	4.17 ^{abc}	6.33 ^{bc}	6.67 ^b
<i>Mbalila bbali</i>	2.00 ^{ab}	0.83 ^b	1.50 ^{ab}	0.83 ^{bc}	1.50 ^a	1.67 ^b	3.67 ^{bc}	3.33 ^{bc}	5.00 ^c	6.33 ^b
<i>Sukaali</i>	1.17 ^{abc}	0.67 ^b	1.67 ^{ab}	0.33 ^c	1.67 ^a	1.67 ^b	3.00 ^c	4.33 ^{abc}	5.50 ^c	7.17 ^{ab}
<i>Kasanda</i>	2.33 ^a	2.00 ^a	2.33 ^a	2.17 ^a	2.83 ^a	3.33 ^{ab}	5.33 ^{abc}	3.83 ^{bc}	6.50 ^{bc}	7.33 ^{ab}
Narospot 1	1.33 ^{abc}	1.00 ^{ab}	1.83 ^{ab}	0.83 ^{bc}	1.67 ^a	2.17 ^{ab}	4.00 ^{bc}	3.00 ^c	5.50 ^c	6.00 ^b
<i>New Kawogo</i>	1.17 ^{abc}	0.83 ^b	1.33 ^{ab}	1.00 ^{bc}	1.50 ^a	1.83 ^b	3.50 ^{bc}	2.83 ^c	6.50 ^{bc}	6.83 ^{ab}
Naspot 8	0.67 ^{bc}	0.67 ^b	1.33 ^{ab}	0.67 ^{bc}	2.00 ^a	2.17 ^{ab}	4.17 ^{bc}	5.50 ^{abc}	8.50 ^{ab}	9.50 ^{ab}
Naspot 12	0.50 ^c	0.83 ^b	1.50 ^{ab}	1.00 ^{bc}	1.83 ^a	1.83 ^b	4.17 ^{bc}	4.33 ^{abc}	7.00 ^{bc}	8.33 ^{ab}
Naspot 13	0.50 ^c	1.00 ^{ab}	1.50 ^{ab}	1.17 ^b	2.50 ^a	5.00 ^a	7.33 ^a	6.83 ^a	10.33 ^a	10.83 ^a
<i>Njule</i>	1.83 ^{abc}	1.67 ^{ab}	1.83 ^{ab}	2.33 ^a	1.83 ^a	4.33 ^{ab}	5.50 ^{ab}	6.00 ^{ab}	7.17 ^{bc}	7.67 ^{ab}

Values along the same column with the same superscript are not significantly different (P < 0.05).

Generally, the solubility of all starch samples increased with rising temperatures. Solubility indicates the degree of intermolecular cross-bonding within the granules (Eke-Ejiofor & Mbaka, 2018). When starch is subjected to high temperatures, the intermolecular bonds within the starch weaken. Virna, Lukmanul, Anshar, Ismail, and Zaidiyah (2016) noted that heating starch in water disrupts its crystalline structure, allowing water molecules to form hydrogen bonds with the free hydroxyl groups of amylose and amylopectin, thereby enhancing solubility. This solubility reflects the soluble amylose and amylopectin that leach out from the starch granules. Variations in solubility may also be attributed to differences among the starch varieties (Virna, Lukmanul, Anshar, Ismail, & Zaidiyah, 2016).

4.2.4 Resistant Starch

Resistant starch levels ranged from 23% to 64% as seen on Table 4.8, showing no significant differences between hybrid and local varieties.

Table 4. 8: Resistant starch in the selected sweet potato varieties

Variety	Resistant Starch (%)
Naspot 8	37.70 ^h
Naspot 12	51.34 ^d
Naspot 13	46.65 ^f
Narospot1	58.76 ^c
Njule	42.82 ^g
Nakakande	64.14 ^a
Mubalila Bbali	59.10 ^e
Kasanda	50.15 ^c
New Kawogo	23.80 ^b
Sukali	62.09 ^b

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

New Kawogo exhibited the lowest resistant starch content, while *Nakakande* had the highest. Kim *et al.* (2020) found that the resistant starch content in various sweet potato varieties ranged from 1.76% to 30.75%, whereas Yong *et al.* (2018) reported values between 29.25% and 43.50% in

China. The content of resistant starch is primarily influenced by factors such as starch structure, genetic differences, maturity, cultivation practices, soil quality, and environmental growing conditions (Zhang *et al.*, 2018). Resistant starch refers to the portion of starch that is not hydrolyzed by starch degrading enzymes and pass through the digestive tract intact (Nugent, 2005). This starch undergoes fermentation in the large intestine, producing short-chain fatty acids like butyric acid, which are vital for maintaining colon health. Resistant starch has gained prominence as a food ingredient in the food industry due to its various physiological benefits including prevention of hypoglycemia, reduced risk of colon cancer, decreased gallstone formation, hypocholesterolemic effects, and weight management (Fuentes-Zaragoza *et al.*, 2011; Nugent, 2005).

4.2.5 Pasting Properties

The pasting properties of the starches exhibited variability across the different varieties as seen on Table 4.9. Pasting quality refers to a substance's ability to exhibit paste-like behavior (Otegbayo *et al.*, 2006). This quality is influenced by the rigidity of the starch granules, which affects their capacity for expansion (Sandhya-Rani & Bhattacharya, 1989). The process of pasting involves the swelling of granules due to heat, the disorganization of starch granules in excess water, the release of molecular components, and ultimately, the complete breakdown of the starch granules (Rajesh & Khatkar, 2017).

Peak or maximum viscosity ranged between 10834 and 14399 cc. Starch from *New Kawogo* had the highest and *Mubalira bballi* had the lowest peak viscosity and the two were significantly different. The peak viscosities from the other starches were not significantly different. It indicates the water holding capacity of a starch (Tsakama, Mwangwela, Manani, & Mahungu, 2010). Peak viscosity is associated with the degree of starch damage (Ikegwu, Nwobasi, Odoh, & Oledinma, 2009).

Trough (minimum) viscosity varied significantly among the starch sources and ranged between 1081 to 5354 cP in Naspot 8 and *Kasanda* respectively. It gauges the paste's resistance to disintegration while cooling (Belay Dereje, 2020). Low cooking losses and better eating quality may be indicated by high trough viscosity. (Asaam *et al.*, 2018).

Table 4. 9: Pasting properties of starch extracted from the different sweet potato varieties

Variety	Peak	Trough	Breakdown	Final Viscosity	Setback	Peak Time	Pasting Temperature
<i>Nakakande</i>	12901 ^{ab}	3139 ^{bcd}	9762 ^{ab}	4550 ^{ab}	1411 ^{bc}	3.8 ^{cd}	74.6 ^{bc}
<i>Mbalila bbali</i>	10834 ^d	3672 ^{abcd}	7162 ^{cd}	4459 ^{ab}	787 ^c	4.0 ^{ab}	74.9 ^{bc}
<i>Sukaali</i>	11326 ^{bcd}	2355 ^{cde}	8971 ^{abc}	3101 ^b	746 ^c	3.7 ^d	76.1 ^{abc}
<i>Kasanda</i>	12025 ^{bcd}	5353 ^a	6671 ^d	5867 ^a	513 ^c	4.1 ^a	76.4 ^{abc}
Narospot 1	12841 ^{abc}	5096 ^{ab}	7744 ^{cd}	5249 ^{ab}	152 ^c	3.9 ^{bc}	77.6 ^{ab}
<i>New Kawogo</i>	14399 ^a	4621 ^{ab}	9778 ^{ab}	5183 ^{ab}	562 ^c	3.9 ^{abc}	78.9 ^a
Naspot 8	11275 ^{cd}	1081 ^e	10194 ^a	3884 ^{ab}	2803 ^a	3.4 ^e	73.9 ^c
Naspot 12	11840 ^{bcd}	3638 ^{abcd}	8202 ^{bcd}	4252 ^{ab}	614 ^c	3.8 ^{cd}	74.4 ^{bc}
Naspot 13	12356 ^{bcd}	1896 ^{de}	10460 ^a	4045 ^{ab}	2149 ^{ab}	3.6 ^d	73.2 ^c
<i>Njule</i>	12530 ^{bc}	4305 ^{abc}	8224 ^{bcd}	5554 ^a	1249 ^{bc}	3.8 ^{cd}	77.8 ^{ab}

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

The breakdown viscosity ranged from 6672 cP for *Kasanda* to 10460 cP for Naspot 13 and was notably different for each variety. This means Naspot 13 had the highest degree of granule disintegration and paste stability (Rajesh & Khatkar, 2017). According to Lee, Hettiarachchy, & Gnanasambandan (1995), breakdown viscosity is influenced by amylose content.

The final viscosity ranged from 3101 cP for *Sukaali* to 5867 cP for *Kasanda*, showing a significant variation amongst the different varieties. As ultimate viscosity is related to greater stability of starch pastes, this suggests that starch from *Kasanda* can form a stable paste or gel after chilling (Virna *et al.*, 2016). Re-association of starch molecules, particularly amylose, causes the creation of a gel structure after cooling, which determines the final viscosity (Ragaee, El Sayed, & Abdel, 2006). It determines the quality of starch-based foods i.e. if the product can gel on cooling (Ikegwu, Okechukwu, & Ekumankana, 2010).

The setback viscosity of starch varied significantly among the different varieties ranging from 152 cP for Narospot 1 to 2803 cP for Naspot 8. Setback viscosity describes the degree of retrogradation with a rise in paste viscosity on cooling (Hardeep, Paras, Haprabhdeep, & Jaspreet, 2013). High values indicate faster aging meaning starch from Naspot 8 would produce products that deteriorate faster relative to Narospot 1 and others.

Peak time (the time required for the starch granules to reach their maximum swelling and form a paste when exposed to heat and moisture) varied significantly between the varieties and was between 3.42 and 4.07 minutes for Naspot 8 and *Kasanda*. It is a measure used in the analysis of starch gelatinization and cooking quality. The shorter the peak time, the faster the starch granules swell and the quicker they form a paste. The cooking time is gauged by peak time (Adebowale, Sanni, & Awonorin, 2005), meaning that starch from Naspot 8 swells rapidly to form a paste relative to *Kasanda* and the other varieties are susceptible to shear induced disintegration. Granules associated with *kasanda* and other starches with a high peak time may swell slowly and be resistant to mechanical damage (Tsakama, Mwangwela, Manani, & Mahungu, 2010).

The pasting or gelatinization temperature varied significantly among the different varieties ranging from 73.2°C for Naspot 13 to 78.9°C for *New Kawogo*. Temperature at which viscosity starts to rise during the heating process is known as the "pasting temperature" (Rajesh & Khatkar, 2017) It shows the bare minimum temperature needed to cook the samples. Hybrid varieties i.e. Naspot 13, 12 and 8 had the lowest pasting temperature (73.2 to 74.4°C) while local varieties had the highest pasting temperature (74.6 to 78.9°C). This may mean that *New Kawogo* (which also had the highest dry matter) may be harder in terms of texture than other varieties and needs more energy to cook. Compared to other starch samples, Naspot 13's starch will cook more quickly and with less energy, saving money and time (Ikegwu, Okechukwu, & Ekumankana, 2010).

In summary, the physicochemical properties of starch extracted from various Ugandan sweet potato varieties exhibited notable variations in characteristics such as starch yield, water holding capacity (WHC), swelling power, solubility, resistant starch, and pasting properties. Starch yield on a wet basis ranged from 15.5% (*Naspot 13*) to 29.6% (*Sukali*), with local varieties yielding more than hybrids. WHC varied slightly between varieties, with *Nakakande* showing the highest (1.20 g/g) and *Sukali* the lowest (0.80 g/g). Swelling power increased with temperature, with

Naspot 13 having the highest swelling power (16.07 g/g) at 90°C. Solubility also increased with temperature, and *Naspot 13* had the highest solubility (10.83%) at 90°C. Resistant starch content ranged from 23% (*New Kawogo*) to 64% (*Nakakande*). Pasting properties, including peak viscosity, breakdown, and setback viscosities, varied across varieties, with *New Kawogo* having the highest peak viscosity (14,399 cP) and *Naspot 8* showing the highest setback viscosity (2,803 cP).

Therefore, the starch properties of Ugandan sweet potato varieties vary significantly, with local varieties generally exhibiting higher starch yields, resistant starch, and pasting properties compared to hybrids. Starches from varieties like *Nakakande* and *Sukali* demonstrated desirable characteristics for certain food applications due to their higher yield and stable pasting properties. Meanwhile, starches like *Naspot 13* exhibited high swelling power and solubility, which may influence texture and cooking time. These starch characteristics are crucial for determining the suitability of sweet potato varieties in diverse food processing applications, from producing gels and pastes to enhancing food texture and stability.

4.3 Characterization of sweet potato products

4.3.1 Rheological Properties of Sweet Potato-Wheat Bread

The substitution of wheat flour with sweet potato flour (both orange-fleshed sweet potato [OFSP] and white-fleshed sweet potato [WFSP]) at varying levels did not significantly affect the protein weakening (α), mixing, or gluten indices (Table 4.10). However, significant differences were observed in dough stability, C1 and C2 as the substitution levels increased. This reduction in dough strength is likely due to the higher proportion of sweet potato flour in the formulations. The increasing levels of substitution were also associated with increased water absorption, particularly at the 40:60 (OFSP) and 17.5:82.5 ratios. The higher fiber content in sweet potato flour, as opposed to wheat flour, likely contributed to this trend. Specifically, OFSP flour showed greater water absorption than WFSP flour, which aligns with its higher fiber content based on proximate analysis (Noorfarahzilah *et al.*, 2014).

This increase in water absorption resulted in weaker dough, ultimately affecting its development and stability. The substitution of sweet potato flour for wheat flour led to reduced dough extensibility, impeding gluten formation and resulting in blends with diminished strength and stability. For instance, the 17.5:82.5 WFSP and 30:70 WFSP formulations exhibited dough stability (C1) values of 7.6 and 4.35, respectively, with significant differences indicating a decrease in stability as sweet potato flour increased. This weakening of the dough can be attributed to higher water absorption, as sweet potato flour takes up more water than wheat flour, leading to reduced dough development and stability (Chikpah *et al.*, 2021).

The overall viscosity of the formulations did not show significant variation, although the maximum value (4.000) was observed in the 10:90 WFSP blend, while the 40:60 WFSP formulation recorded the minimum value (2.000). The control (100% wheat flour) had a higher viscosity index (5.500), which diminished with increasing sweet potato flour substitution. The decrease in viscosity is primarily due to the dilution of gluten by sweet potato flour, which lacks gluten-forming proteins, thus lowering the viscosity of the dough (Noorfarahzilah *et al.*, 2014).

Table 4. 10: Rheological Properties of Sweet Potato Bread Flour

	C1 (MIN)	CS (MIN)	α (Nm/min)	β (Nm/min)	γ (Nm/min)	Absorpti on	Mixi ng	Glute n+	Viscos ity	Amyla se	Retro gradation
100 W	9.150 ^a	9.200 ^a	-0.114 ^d	0.382 ^b	-0.058 ^e	4.000 ^c	3.000 ^a	4.000 ^a	5.500 ^a	3.500 ^a	6.500 ^a
10% WFSP90% W	7.250 ^b	5.885 ^b	-0.090 ^c	0.432 ^a	-0.022 ^{ab}	1.000 ^d	2.000 ^a	1.500 ^b	4.500 ^{ab}	4.000 ^a	5.500 ^{abc}
10% OFSP90% W	7.150 ^b	5.115 ^c	-0.088 ^{bc}	0.449 ^a	-0.020 ^a	4.000 ^c	1.500 ^a	1.500 ^b	4.000 ^{ab}	3.500 ^a	6.000 ^{ab}
40% OFSP60% W	5.050 ^{de}	6.165 ^b	-0.070 ^a	0.232 ^e	-0.030 ^{bc}	8.000 ^a	2.000 ^a	2.500 ^a	1.500 ^c	1.500 ^b	2.500 ^{de}
17.5% OFSP82.5 % W	6.300 ^{bc}	5.135 ^c	-0.079 ^{abc}	0.379 ^b	-0.031 ^c	6.000 ^b	1.500 ^a	1.000 ^b	2.500 ^{bc}	3.000 ^a	4.000 ^{bcd}
17.5% WFSP82. 5% W	7.350 ^b	4.975 ^c	-0.091 ^c	0.398 ^b	-0.049 ^d	1.000 ^d	2.000 ^a	1.000 ^b	2.500 ^{bc}	3.000 ^a	3.500 ^{cde}
25% OFSP75% W	6.900 ^b	5.065 ^c	-0.072 ^{ab}	0.349 ^c	-0.022 ^{ab}	1.000 ^d	2.000 ^a	1.000 ^b	2.500 ^{bc}	2.500 ^a	2.500 ^{de}
40% WFSP60% W	4.550 ^e	5.090 ^c	-0.065 ^a	0.336 ^c	-0.025 ^{abc}	4.500 ^c	1.500 ^a	1.500 ^b	2.000 ^{bc}	3.000 ^a	2.000 ^{de}
25% WFSP75% W	6.200 ^{bc}	5.115 ^c	-0.072 ^{ab}	0.391 ^b	-0.049 ^d	1.000 ^d	2.000 ^a	1.000 ^b	3.000 ^{ab}	1.500 ^b	3.000 ^{de}
30% OFSP70% W	5.100 ^{cd}	5.960 ^b	-0.072 ^{ab}	0.290 ^d	-0.060 ^e	6.500 ^b	1.500 ^a	2.500 ^a	1.500 ^c	2.000 ^a	3.000 ^{de}
30% WFSP70% W	4.200 ^e	5.025 ^c	-0.070 ^a	0.328 ^c	-0.058 ^e	4.000 ^c	1.500 ^a	1.500 ^b	1.500 ^c	2.000 ^a	1.500 ^e

There are no significant differences between values in the same column with the same superscripts.

α - Protein weakening; β - Starch gelation speed; γ - Enzyme degradation speed

Significant differences in retrogradation were noted with increasing sweet potato substitution. The control (100% wheat) had a retrogradation index of 6.5, whereas the 10:90 OFSP blend had an index of 5.50. As substitution increased, the retrogradation index dropped to 2.000 for the 40:60 WFSP blend. This decline suggests greater moisture retention in the dough, which can negatively affect the dough by increasing its mass and reducing its leavening ability. Optimal retrogradation was observed in the 100% wheat flour formulation, as deviations (either higher or lower) negatively impacted the final product's quality. The lower retrogradation of sweet potato flour is attributed to its starch composition, which forms glycosidic linkages that limit starch hydrolysis by alpha-amylase, thus reducing retrogradation in sweet potato-based formulations (Chikpah *et al.*, 2021).

There were Significant differences in the β (starch gelation speed) and γ (enzyme degradation speed) values. The 10% OFSP to 90% wheat composite flour exhibited the highest starch gelatinization speed. As the substitution level increased, gelation rates significantly decreased, likely due to the minimal amounts of damaged starch in sweet potato flour. The control formulation (100% wheat) demonstrated a high enzyme degradation speed index, whereas formulations containing sweet potato flour generally exhibited lower degradation indices, further influencing dough performance and final product quality.

In summary, increasing the substitution of wheat flour with sweet potato flour led to significant changes in the dough's rheological properties, with a marked reduction in dough stability, extensibility, and viscosity, which impacted the quality and texture of the final bread product. However, the increased water absorption and lower retrogradation of sweet potato flour may present potential opportunities for product optimization, depending on the desired end-product characteristics.

4.3.1.2 Texture Analysis of Sweet Potato-Wheat Bread

Texture is a critical attribute used to evaluate food quality and its acceptability (Bou-Orm & Jury, 2021). It includes aspects such as firmness, springiness, and cohesiveness. No significant differences were observed in springiness among the different formulations (including the control),

regardless of the percentage of wheat replaced by sweet potato flour (Table 4.11). High springiness in bread is generally favorable, as it is associated with freshness and reduced crumb brittleness (Matos & Rosell, 2012). All sweet potato-wheat blends displayed similar springiness values, maintaining a desirable texture across the board.

Cohesiveness, another key texture parameter, did not significantly differ between the control (100% wheat flour) and the sweet potato-wheat flour composites. The cohesiveness values for all formulations were relatively stable, though a slight decrease in cohesiveness was observed as the proportion of sweet potato flour increased. At 10% sweet potato flour inclusion, the cohesiveness was highest (6.23), surpassing even the 100% wheat flour formulation. This indicates that low levels of sweet potato flour do not compromise cohesiveness, but as the percentage of sweet potato flour increases, cohesiveness tends to decrease. This can be attributed to moisture loss during baking, starch retrogradation, and weakened protein interactions in the dough (Feili et al., 2013). Higher cohesiveness is beneficial, as it helps the bread maintain its structure during chewing, while lower cohesiveness results in a crumblier texture (Onyang, *et al.*, 2011).

Firmness showed significant variation across the different formulations. As the proportion of sweet potato flour increased, so did the firmness, with values ranging from 2.82 N at 10% sweet potato flour to 10.97 N at 40% sweet potato flour. The 100% wheat flour bread had a firmness of 6.85 N. These results suggest that increasing sweet potato flour content leads to firmer bread crumbs, likely due to increased moisture loss, starch retrogradation, and the interaction between gluten and fibrous components in sweet potato flour (Chikpah *et al.*, 2021). Firmer bread requires more force to compress, which can be desirable or undesirable depending on consumer preferences. Chikpah *et al.* (2021) similarly found that increasing the percentage of orange-fleshed sweet potato flour in bread formulations resulted in higher crumb hardness, reflecting similar trends to the current study.

Overall, sweet potato flour substitution up to 40% leads to increased bread firmness and slight reductions in cohesiveness, though the springiness remains consistent. However, maintaining an optimal balance between firmness and cohesiveness may be important to achieve a product that is both acceptable to consumers and structurally stable.

In summary, substituting wheat flour with sweet potato flour up to 40% significantly affects the texture of bread, increasing firmness while maintaining acceptable levels of springiness and

cohesiveness. The increase in firmness may be due to moisture loss and starch retrogradation, while cohesiveness slightly decreases with higher sweet potato flour content. Despite these changes, springiness remains consistent, indicating that the bread retains a desirable texture. Achieving an optimal balance between firmness and cohesiveness is essential for consumer acceptability. Therefore, careful adjustment of sweet potato flour levels can enhance the overall quality of the bread, catering to consumer preferences for texture.

Table 4. 11: Texture analysis results of the sweet potato bread.

Product	Firmness (N)	Springiness	Cohesiveness
100% W	6.85abcd	0.790a	0.485bcd
OFSP (Naspot 13)			
40% OF	10.97 ^a	0.823 ^a	0.480 ^{cd}
30% OF	6.82 ^{abc}	0.793 ^a	0.510 ^{bc}
25% OF	4.81 ^{bcd}	0.867 ^a	0.523 ^{bc}
17.5% OF	8.71 ^{ab}	0.790 ^a	0.523 ^{bc}
10% OF	2.82 ^d	0.897 ^a	0.623 ^a
WFSP (Kasanda)			
40% K	10.16 ^a	0.857 ^a	0.407 ^e
30% K	7.43 ^{abc}	0.763 ^a	0.410 ^e
25% K	8.47 ^{abc}	0.790 ^a	0.440 ^{de}
25% K	6.00 ^{abcd}	0.810 ^a	0.490 ^{bcd}
17.5% K	5.24 ^{bcd}	0.763 ^a	0.437 ^{de}
10% K	4.21 ^{cd}	0.893 ^a	0.547 ^b

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

4.3.1.3 Sensory Characteristics of Sweet Potato-Wheat Bread

The sensory characteristics of sweet potato-wheat composite bread varied with the proportion of sweet potato flour incorporated into the formulation (Table 4.12). As the proportion of sweet potato flour increased whether from orange-fleshed sweet potato or white-fleshed sweet potato,

sensory scores for several attributes, including flavor, texture, and overall acceptability, generally decreased. This decline was particularly notable at higher substitution levels (30% and 40%).

The inclusion of wheat flour significantly enhanced the sensory attributes of the bread, with the 100% wheat (control) sample consistently receiving the highest scores across nearly all sensory parameters. Conversely, the WFSP 40:60 composite had the lowest scores, particularly in attributes like texture and flavor. The lower sensory ratings at higher sweet potato flour inclusion levels could be attributed to the weakening of the dough's elastic properties. As the sweet potato flour proportion increases, the gluten network becomes diluted, reducing its ability to retain gas during fermentation. This, in turn, leads to a denser crumb structure and a coarser texture (Noorfarahzilah et al., 2014). The functional components of bread such as protein, starch, and hydrocolloids also contribute to texture variation (Sibanda, Ncube, & Ngoromani, 2015).

Flavor is a critical sensory attribute, and the flavor scores decreased significantly at a 30% sweet potato flour substitution for both OFSP and WFSP composites. This decline mirrors the findings of Nakisozi (2018), who reported that the flavor of composite bread made from wheat, banana, and cassava flour diminished as the proportion of alternative flours increased. It is essential to note that consumers are often more familiar with and prefer the flavors of products they frequently consume. Thus, higher wheat content aligns with better flavor scores, likely because of consumer familiarity with the flavor profile of wheat-based bread.

In terms of overall acceptability, the composite bread with 15% to 30% sweet potato flour had significantly lower scores compared to the control. However, substitutions of 10% to 12.5% yielded bread with sensory qualities that were comparable to those of the 100% wheat bread. These findings indicate that moderate sweet potato flour inclusion (around 10%) can be an effective way to lower wheat content while maintaining consumer satisfaction. Both OFSP and WFSP flour present viable alternatives to wheat flour, especially at lower substitution levels, which offer cost-effective solutions to the rising price of wheat without significantly compromising sensory appeal.

Aroma also plays a vital role in consumer appeal. Among the sweet potato-wheat bread samples, the WFSP 10:90 formulation had the highest aroma score (6.5), while the WFSP 40:60 formulation received the lowest (4.8). The reduction in aroma scores at higher sweet potato flour inclusion

levels could be linked to the distinct, less familiar odor of sweet potato, which consumers may find less appealing compared to the neutral or pleasant aroma of wheat bread.

Table 4. 12: Sensory analysis results of bread.

Product	Appearance	Crust color	Crumbs Color	Aroma	Taste	Texture	Tenderness	Flavor	After taste	acceptability
100W	7.3 ^a	7.2 ^a	7.2 ^a	7.0 ^a	7.3 ^a	7.3 ^a	7.3 ^a	7.0 ^a	7.2 ^a	7.6 ^a
WFSP:W										
10:90	6.9 ^{ab}	7.1 ^{ab}	7.3 ^a	6.5 ^{ab}	6.9 ^{ab}	6.3 ^{ab}	6.3 ^{ab}	6.4 ^{ab}	6.9 ^{abc}	6.6 ^{abc}
OFSP:W										
10:90	6.6 ^{abc}	6.8 ^{abc}	7.1 ^a	5.9 ^{abcd}	6.7 ^{ab}	6.3 ^{ab}	7.1 ^a	6.1 ^{abc}	7.0 ^{ab}	7.1 ^{ab}
WFSP:W										
17.5:82.5	6.4 ^{abc}	6.4 ^{abc}	6.8 ^a	5.9 ^{abc}	6.2 ^{abc}	6.0 ^{bc}	6.2 ^{ab}	5.9 ^{abc}	6.5 ^{abc}	6.3 ^{abcd}
OFSP:W										
17.5:82.5	6.2 ^{bcd}	6.7 ^{abc}	7.0 ^a	5.6 ^{bcd}	6.5 ^{ab}	5.9 ^{bc}	6.2 ^{ab}	5.9 ^{abc}	6.4 ^{abc}	6.4 ^{abcd}
OFSP:W										
25:75	5.9 ^{bcdef}	6.2 ^{abc}	6.6 ^{ab}	5.4 ^{bcd}	6.1 ^{abc}	5.7 ^{bcd}	6.2 ^{ab}	5.8 ^{bc}	6.4 ^{abc}	6.3 ^{abcd}
WFSP:W										
25:75	6.0 ^{bcde}	6.4 ^{abc}	6.2 ^{abc}	5.81 ^{bcd}	5.8 ^{bc}	5.7 ^{bcd}	5.8 ^{bc}	5.7 ^{bc}	6.0 ^{abc}	5.9 ^{bcd}
OFSP:W										
30:70	5.1 ^{def}	5.9 ^{bc}	5.6 ^{bc}	5.3 ^{bcd}	5.8 ^{bc}	5.2 ^{cd}	5.6 ^{bc}	5.6 ^{bc}	6.0 ^{abc}	5.9 ^{bcd}
WFSP:W										
30:70	5.5 ^{cdef}	5.9 ^{abc}	5.6 ^{bc}	5.7 ^{bcd}	5.6 ^{bc}	5.0 ^{cd}	5.3 ^{bc}	5.3 ^{bc}	5.7 ^{bc}	5.5 ^{cd}
OFSP:W										
40:60	4.9 ^f	5.7 ^c	5.3 ^c	4.9 ^{cd}	5.1 ^c	4.9 ^d	5.0 ^c	5.1 ^c	5.6 ^c	5.3 ^d
WFSP:W										
40:60	4.95 ^{ef}	5.6 ^c	5.3 ^c	4.8 ^d	4.9 ^c	4.9 ^d	5.0 ^c	5.1 ^c	5.6 ^c	5.1 ^d

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

In summary, sweet potato flour substitution in bread formulations negatively impacted sensory attributes such as flavor, texture, and overall acceptability, particularly at higher substitution levels. However, moderate substitution of up to 10% to 12.5% produced bread with sensory qualities similar to that of 100% wheat bread, suggesting its potential as an alternative flour source to mitigate rising wheat costs.

Therefore, while increasing the substitution of wheat flour with sweet potato flour negatively impacted sensory characteristics such as flavor, texture, and overall acceptability especially at

higher substitution levels moderate substitutions of 10% to 12.5% sweet potato flour resulted in bread with sensory attributes comparable to 100% wheat bread. This suggests that sweet potato flour, particularly at lower substitution levels, offers a promising alternative to reduce wheat dependency without significantly compromising consumer satisfaction. The inclusion of sweet potato flour could serve as a cost-effective solution, particularly in response to rising wheat prices, while maintaining desirable sensory qualities in bread.

4.3.1.4 Proximate Composition of Bread

The proximate analysis of the sweet potato-wheat composite bread revealed no significant differences in the crude moisture, ash, protein, fat, fiber, and carbohydrate content between bread made with orange-fleshed sweet potato (OFSP) and white-fleshed sweet potato (WFSP) flour (Table 4.13). At a 10% wheat flour substitution level, the moisture content was 65.6% for the OFSP-wheat composite bread and 66.9% for the WFSP-wheat composite bread. Ash content was 2.69% and 2.48% for OFSP and WFSP, respectively, while fat content was 1.83% for OFSP and 1.94% for WFSP. The crude protein content was slightly higher in the OFSP bread (4.67%) compared to the WFSP bread (4.50%), and crude fiber was marginally greater in the OFSP bread (1.32%) than in the WFSP bread (1.17%). Carbohydrate content was 25.20% in the OFSP bread and 24.14% in the WFSP bread, aligning with similar findings from Aniedu and Agugo (2010).

In comparison to previous studies, Ogbodogbo, Oluwalana, and Malomo (2012) reported lower values for some of the proximate components, including protein (2.7%), crude fiber (0.85%), fat (2.43%), ash (0.8%), and moisture content (34.09%), but significantly higher carbohydrate content (59.13%). However, their reported protein content of 11.28%, fat content of 4.68%, ash content of 2.65%, crude fiber content of 2.63%, and moisture content of 43.53% with 10% wheat flour substitution closely aligns with the findings of the current study.

The relatively low fiber content in this study, though not significantly different between the two bread formulations, underscores the potential for improvement. A high-fiber diet is beneficial in managing conditions like diabetes, hypertension, obesity, and digestive disorders such as hemorrhoids (Wafula *et al.*, 2022). This is especially pertinent since crude fiber adds bulk to food,

facilitating bowel movements and enhancing overall gastrointestinal health. The mineral content, inferred from the ash content, indicates that bread made from OFSP could be a valuable source of essential nutrients for consumers (Nakisozi, 2018).

No significant differences were found in the fat content between the OFSP and WFSP bread. Fat plays a vital role in dough processing as it aids in incorporating and retaining air during mixing, thereby contributing to a softer crumb structure and increased loaf volume. Additionally, fat improves the bread's tenderness by retaining moisture, providing lubrication, and enhancing flavor, color, and anti-staling properties (Nakisozi, 2018). Protein content in the bread is largely attributable to the gluten present in wheat flour, which is essential for dough elasticity and gas retention during baking (Shamima *et al.*, 2023).

In summary, the proximate composition of the sweet potato-wheat composite bread was similar for both OFSP and WFSP formulations, showing no significant differences in moisture, ash, protein, fat, fiber, or carbohydrate content at a 10% wheat flour substitution level. These findings suggest that both OFSP and WFSP flours are viable alternatives for partially replacing wheat flour in bread without compromising its proximate nutrient content.

Table 4. 13: Proximate composition (%) of sweet potato bread (wet basis).

Product	Moisture	Ash (wet basis)	Fat (wet basis)	Crude protein	Crude Fibre (wet basis)	Fibre carbo	Energy, Kcal/100g
OFSP 10%	65.6 ^a	2.69 ^a	1.83 ^a	4.67 ^a	1.32 ^a	25.20 ^b	138.3 ^b
WFSP 10%	66.9 ^a	2.48 ^a	1.94 ^a	4.50 ^a	1.17 ^a	24.14 ^b	133.7 ^b

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

Therefore, the proximate composition of sweet potato-wheat composite bread made from both orange-fleshed sweet potato (OFSP) and white-fleshed sweet potato (WFSP) flour showed no significant differences in key nutrient components such as moisture, ash, fat, protein, fiber, and carbohydrates at a 10% wheat flour substitution level. Besides the high beta-carotene content in *Naspot 13*, both OFSP and WFSP flours proved to be viable alternatives for partially replacing wheat flour without compromising the nutritional value of the bread. These findings suggest that

either type of sweet potato flour can be used to enhance the nutritional profile of bread, making it a potential cost-effective and nutrient-enriching option in bread formulations.

4.3.2 Characterization of Sweet Potato-Wheat Cake

4.3.2.1 Texture Characterization

The firmness of the sweet potato-wheat cake samples ranged from 5.08 to 8.21 N (Table 4.14), demonstrating significant changes upon the substitution of sweet potato flour for wheat flour. Cakes with sweet potato flour exhibited greater firmness compared to the control made entirely from 100% wheat flour. This trend aligns with previous findings by Tarek, Hemmat, and Emad (2015), who noted that incorporating sweet potato flour in wheat-based formulations reduced the extensibility of the final product. Extensibility is primarily associated with gluten content in wheat flour, and as sweet potato flour lacks gluten, its inclusion reduces gluten content, thereby lowering extensibility and increasing firmness.

As indicated in the proximate analysis, the cakes with orange-fleshed sweet potato (OFSP) flour had a higher fiber and ash content compared to those made from 100% wheat flour. These compositional changes likely contributed to the observed increase in cake firmness. The increase in fiber content, coupled with a reduced gluten network, limits the dough's extensibility and creates a denser crumb structure. As noted by Manohar and Haridas (1999), the absorption of free water by hydrophilic components during mixing increases dough viscosity, which leads to a more rigid structure with less available water, making the cakes firmer.

Similarly, Aslam (2014) observed that reduced moisture content in baked goods, such as biscuits, increased their hardness. Cakes with higher amounts of OFSP flour (60%, 70%, and 80%) exhibited increased firmness, particularly in comparison to those made with white-fleshed sweet potato (WFSP) flour. This increase in firmness is likely due to the interaction between the limited gluten from wheat flour and the fiber-rich sweet potato components, forming a dense three-dimensional network that results in a firmer cake texture. The findings further indicate that higher substitution levels of sweet potato flour (both OFSP and WFSP) yield firmer cakes due to the reduction in gluten content and the influence of fiber.

In summary, the texture of sweet potato-wheat cakes was notably firmer with increasing sweet potato flour substitution, attributed to reduced gluten content and increased fiber, limiting extensibility and enhancing firmness.

Table 4. 14: Texture analysis results of sweet potato-wheat cake.

CAKE SAMPLES	Area 1 (m)	Firmness (N)
100W	0.000 ^b	5.080 ^c
OFSP: W 80:20	26.800 ^a	5.978 ^{bc}
OFSP: W 70:30	41.800 ^a	8.206 ^a
OFSP: W 60:40	28.600 ^a	5.448 ^{bc}
WFSP: W 80:20	29.000 ^a	6.900 ^{abc}
WFSP: W 70:30	36.600 ^a	7.378 ^{ab}
WFSP: W 60:40	27.000 ^a	5.456 ^{bc}
P value	< 0.0001	0.000

Values along the same column with the same superscript are not significantly different ($P < 0.05$).

4.3.2.2 Sensory analysis of sweet potato cake

Sensory evaluation is critical for determining the quality of sweet potato-based products, aligning them with consumer preferences. Appearance, texture, flavor (aroma and taste), and other sensory attributes significantly influence consumer choices (Aslam, 2014). In this study, sensory assessment was conducted using a 9-point hedonic scale, which rated characteristics like taste, appearance, texture, aroma, and overall acceptability of the sweet potato-wheat cakes.

The statistical analysis of sensory data revealed no significant differences across taste, flavor, aftertaste, aroma, color, crust color, appearance, texture, tenderness, and overall acceptability between the cake samples (Table 4.15). However, the control sample (100% wheat flour) generally received the highest ratings across most attributes, indicating that consumer preference tended to decline as sweet potato flour substitution increased (Manohar & Haridas, 1999).

Table 4. 15: Sensory results of cake samples.

Samples	Appetite	Crust color	Crumb Color	Aroma	Taste	Texture	Tenderness	Flavor	After taste	General acceptability
100W	7 ^a	7 ^a	7 ^a	6 ^a	7 ^a	7 ^a	7 ^a	6 ^a	6 ^a	7 ^{ab}
OFSP:W 80:20	5 ^b	5 ^a	6 ^a	5 ^a	6 ^a	5 ^b	5 ^b	5 ^a	6 ^a	6 ^b
OFSP:W 70:30	6 ^a	6 ^a	7 ^a	6 ^a	6 ^a	6 ^{ab}	6 ^{ab}	6 ^a	6 ^a	6 ^{ab}
OFSP:W 60:40	7 ^a	7 ^a	7 ^a	6 ^a	6 ^a	6 ^{ab}	6 ^{ab}	6 ^a	6 ^a	6 ^{ab}
WFSP:W 80:20	6 ^{ab}	6 ^a	6 ^a	6 ^a	6 ^a	6 ^{ab}	6 ^{ab}	6 ^a	6 ^a	6 ^{ab}
WFSP:W 70:30	7 ^a	6 ^a	7 ^a	6 ^a	7 ^a	6 ^{ab}	6 ^{ab}	6 ^a	6 ^a	7 ^{ab}
WFSP:W 60:40	7 ^a	7 ^a	6 ^a	6 ^a	7 ^a	7 ^a	7 ^{ab}	7 ^a	7 ^a	7 ^a

There are no significant differences between values in the same column with the same superscripts ($P < 0.05$).

Cakes made with 60% white-fleshed sweet potato (WFSP) flour were rated significantly higher in terms of overall acceptability than those made with orange-fleshed sweet potato (OFSP) flour at the same substitution level. The lower acceptability of cakes made with OFSP may be attributed to a slight off-taste, which could have negatively influenced the flavor perception of the panelists (Tarek *et al.*, 2015).

The control sample (100% wheat) was also rated softer than the sweet potato-substituted cakes. This could be explained by the reduced gelation in sweet potato flour-based doughs (as discussed in the bread rheology section), resulting in a firmer texture due to the higher fiber content (Aslam, 2014). The fiber in both WFSP and OFSP interacts with wheat gluten to form a more rigid structure, thus reducing the softness of the cake, which was less preferred by the panelists (Manohar & Haridas, 1999).

The appearance scores of the cakes were also influenced by the type and proportion of sweet potato flour. Cakes with 80% OFSP substitution received the lowest appearance score, likely due to the intense yellow hue of the OFSP flour. When combined with caramelization during baking, this produced a dark orange color that panelists found less appealing (Tarek *et al.*, 2015).

In summary, the sensory evaluation revealed a decline in consumer preference as the substitution of sweet potato flour increased, with cakes made from 100% wheat and 60% WFSP scoring highest for overall acceptability.

4.3.2.3 Proximate composition of sweet potato cakes

The ash content of cakes made from Naspot 13 and Kasanda sweet potato varieties ranged from 2.27% to 2.65%, showing no significant difference from the control (100% wheat cake), which had 2.70% ash (4.16). This suggests that cakes made with sweet potato flour have a comparable ash content to those made entirely with wheat flour. Similarly, Okorie & Onyeneke (2012) found that the inclusion of sweet potato flour did not significantly alter the ash content in composite flours.

The moisture content of the sweet potato cakes varied between 13.78% and 15.80%, while the control wheat cake had a significantly higher moisture content at 18.58%. Tarek, Hemmat, & Emad (2015) reported higher moisture contents in sweet potato-wheat cakes, ranging between 21.84% and 28.13%, which may be attributed to difference in the sweet potato varieties and processing conditions. In comparison, Okorie & Onyeneke (2012) also noted higher moisture levels in their sweet potato composite flours (23.99% to 27.22%), highlighting the potential impact of processing methods on moisture retention.

The crude protein content in the sweet potato cakes ranged between 5% and 7%, with the 100% wheat flour cake showing significantly higher protein levels. Sweet potatoes generally have a lower protein content compared to wheat, which is consistent with findings from Kindane *et al.* (2013), who reported protein levels of 4.62% in orange-fleshed sweet potato flour, compared to 10.72% in wheat flour. Similarly, Okorie & Onyeneke (2012) found lower protein levels in sweet potato-wheat composite flours compared to wheat-only products, supporting the notion that sweet potato flour reduces the overall protein content of baked products.

The fat content across the various cake formulations did not show significant differences, although relatively high fat levels were observed due to the fat-rich nature of the cake formulations. Tarek *et al.* (2015) observed a similar trend in their study, where the fat content of cakes made with sweet potato flour remained consistent with those made entirely of wheat flour.

Crude fiber content varied significantly, with cakes containing higher proportions of OFSP flour showing increased fiber content. This aligns with findings from Wafula *et al.* (2022), who emphasized that orange-fleshed sweet potato products tend to have higher fiber content due to the nature of the sweet potato variety. Fiber is beneficial for digestive health and helps in reducing the risk of conditions like hemorrhoids and obesity, as highlighted in their study.

The carbohydrate content was highest in the 100% wheat cake, but cakes made with sweet potato flour still contained significant carbohydrate levels. Both wheat and sweet potato flours are carbohydrate-dense, as observed by Kindane *et al.* (2013), who reported similar carbohydrate-rich profiles in both types of flours.

Table 4. 16: Proximate composition (%) of sweet potato cake

Sample	Ash Content	Moisture Content	Crude Protein	Crude Fibre	Carbohydrates	Fat Content
100W Cake	2.70 ^a	18.54 ^a	10.475 ^a	2.308 ^b	40.964 ^c	25.018 ^a
80%OFSP cake	2.65 ^a	15.80 ^{bc}	6.001 ^c	4.340 ^a	30.863 ^a	24.912 ^a
60%OFSP cake	2.54 ^{ab}	15.57 ^c	7.010 ^b	2.165 ^b	32.352 ^a	24.189 ^a
80%WFSP cake	2.27 ^c	13.78 ^d	5.373 ^c	1.482 ^b	34.186 ^{ab}	25.814 ^a
60%WFSP cake	2.29 ^{bc}	15.96 ^b	6.781 ^b	1.333 ^b	31.968 ^a	25.686 ^a

There are no significant differences between values in the same column with the same superscripts ($P < 0.05$).

In summary, proximate composition of sweet potato-wheat composite cakes reveals that using sweet potato flour in place of wheat flour will not drastically alter the nutritional profile, although it may slightly reduce moisture and protein content. Products made with sweet potato flour, particularly those using orange-fleshed varieties, are good sources of fiber and energy, contributing to a balanced and nutrient-rich diet.

4.3.2.4 Vitamin A and Beta carotene composition of sweet potato cake

At an 80% substitution of wheat flour with sweet potato flour, cakes made with orange-fleshed sweet potato (OFSP) flour had significantly higher vitamin A content (6589.7 µg/100 g) and beta-carotene levels (141.2 ppm) compared to cakes made with white-fleshed sweet potato (WFSP) flour, which had vitamin A levels of 730.2 µg/100 g and beta-carotene levels of 13.6 ppm (Table 4.17). Wafula *et al.*, (2022) reported that orange-fleshed sweet potato flakes contain 1443.2 µg/100 g of vitamin A, which is lower than the values found in these cakes. This discrepancy could be because of differences in sweet potato varieties, storage conditions, and the specific effects of processing on nutrient retention. Greene and Bowell-Benjamin (2004) found that although beta-carotene is sensitive to heat, a substantial amount is retained in orange-fleshed sweet potatoes after baking, which aligns with this study's findings that OFSP still retained considerable beta-carotene after processing.

Table 4. 17: Vitamin A results of selected cake samples.

Samples	Vitamin A (µg/100 g)	Beta carotene (ppm)
80% OFSP Cake	6589.7± 936.0 ^a	141.2±19.213 ^b
80% WFSP Cake	730.2.5± 66 ^b	13.6± 1.19 ^a

There are no significant differences between values in the same column with the same superscripts (P < 0.05).

Gurmu and Husseins (2014) noted that OFSP typically contains vitamin A levels ranging from 3000 to 16,000 µg/100 g, which falls within the expected range for the vitamin A content found in cakes made with OFSP flour. Despite the potential for nutrient loss due to heat during baking, OFSP still contributes significantly to the vitamin A content of the final product, making it an excellent addition to combat vitamin A deficiency.

In summary, increasing sweet potato flour inclusion, especially with orange-fleshed sweet potato (OFSP), led to firmer cakes due to reduced gluten and higher fiber content. Sensory evaluation showed a decline in acceptability as sweet potato flour substitution rose, with 100% wheat flour cakes preferred for taste and texture. Proximate analysis showed no major changes in nutritional

content, though cakes with sweet potato flour had lower moisture and protein but higher fiber. OFSP cakes also had significantly higher levels of vitamin A and beta-carotene, highlighting their nutritional value, particularly for combating vitamin A deficiency.

In conclusion, sweet potato flour can be a valuable ingredient for partially substituting wheat flour in cake formulations, with potential health benefits such as increased fiber and vitamin A content. However, the substitution leads to a firmer texture and a reduction in sensory acceptability as the proportion of sweet potato flour increases. Cakes with moderate sweet potato flour inclusion (such as 60% WFSP) may offer a good balance between nutritional enhancement and consumer preference. The use of orange-fleshed sweet potato (OFSP) in higher substitutions offers significant nutritional benefits, especially in providing a rich source of beta-carotene and vitamin A, making it a promising option for improving the healthfulness of cake products.

4.3.3 Characterization of sweet potato cookies

4.3.3.1 Texture analysis of selected cookie samples

The texture characteristics of the sweet potato cookies were evaluated through fracturability and hardness tests. The fracturability values ranged from 0.470 to 0.705 mm, while the hardness values ranged from 14.833 to 48.000 N (Table 4.18). There were no significant differences in fracturability across any of the samples, including the control (100% wheat flour), regardless of the level of sweet potato flour substitution. It indicates that addition of sweet potato flour did not affect the structural integrity or the cookie's ability to break apart upon compression.

However, the hardness of the cookies varied significantly. The control cookies, made with 100% wheat flour, were softer (14.833 N) compared to cookies made with sweet potato flour. Specifically, cookies made with orange-fleshed sweet potato (OFSP) flour were much harder (36.833 to 48.000 N) than those made with white-fleshed sweet potato (WFSP) flour (19.800 to 31.667 N). Hardness increased with a higher level of sweet potato flour substitution, particularly with OFSP flour. The difference in hardness can be attributed to the varying levels of fiber and ash content in the sweet potato flour, which affect the dough's ability to retain moisture and its overall structure.

The hardness of cookies is influenced primarily by the gluten and fiber content. As demonstrated in the proximate analysis, cookies containing OFSP had higher fiber and ash content compared to those made with WFSP flour and the control (100% wheat flour). This increased fiber and ash content contributed to the cookies' hardness because of their ability to absorb more water. According to Tiruneh et al. (2018), fiber-enriched flours, like sweet potato flour, tend to have a higher water absorption capacity. OFSP flour, with its water absorption capacity of 2.375 ml/g, absorbs water faster than wheat flour (1 ml/g), resulting in a dough that is less extensible and more viscous. This leads to harder cookies, a phenomenon observed in biscuit dough by Manohar & Haridas (1999).

In contrast, Aslam (2014) found that increased moisture content typically reduces biscuit hardness. However, other studies, including Sukhcharn-Singh (2014), suggest that as moisture content decreases, hardness increases. The higher fiber content in OFSP flour also forms a firm, three-dimensional structure with gluten, which further contributes to the increased hardness observed in the cookies with higher levels of OFSP substitution.

Table 4. 18: Table showing texture results of sweet potato cookie samples

SAMPLES	Fracturability (mm)	Hardness (N)
W 100	0.700 ^a	14.833 ^c
W: WFSP 40:60	0.653 ^a	20.333 ^{bc}
W: WFSP 30:70	0.705 ^a	31.667 ^{abc}
W: WFSP 20:80	0.470 ^a	19.800 ^{bc}
W: OFSP 40:60	0.622 ^a	43.000 ^a
W: OFSP 30:70	0.603 ^a	36.833 ^{ab}
W: OFSP 20:80	0.680 ^a	48.000 ^a
P value	0.226	< 0.0001

There are no significant differences between values in the same column with the same superscripts (P < 0.05).

The texture analysis showed that sweet potato flour, particularly OFSP, significantly influences the hardness of cookies without affecting their fracturability. The increased hardness is associated

with the higher fiber and ash content, as well as the increased water absorption capacity of OFSP flour, which reduces dough extensibility and increases viscosity.

4.3.3.2 Sensory analysis of cookie samples

The sensory evaluation of cookies (Table 4.19), made with sweet potato flour substitutions revealed no noticeable differences in appearance, crumb color, aroma, taste, flavor, or overall acceptability compared to the control sample (100% wheat flour). However, significant differences were observed in the crust color, texture, and tenderness. These differences were mainly attributed to the caramelization of free sugars in the sweet potato flour and the Maillard reaction during baking, which contributed to the appealing color and texture of the cookie crust, leading to higher panelist ratings (Manohar & Haridas, 1999; Sukhcharn-Singh, 2014).

Cookies substituted with white-fleshed sweet potato (WFSP) flour at 60% and 80% were significantly softer than other samples, likely due to the higher fiber and simple sugar content in WFSP flour. This resulted in a softer texture and greater tenderness, which panelists found favorable. The natural sweetness of WFSP flour also contributed to a higher general acceptability score of 7, indicating the cookies were well-liked. In contrast, cookies made with orange-fleshed sweet potato (OFSP) flour received lower acceptability scores (6), which could be due to the less appealing orange color and the lower simple sugar content in OFSP flour. Similar findings were reported by Tiruneh, Emire, & Hailu (2018), where color and sugar content significantly influenced consumer preferences for sweet potato-based products.

The Maillard reaction, a non-enzymatic browning process occurring during baking, enhanced the flavor and appearance of the cookies by producing dark-colored molecules from the interaction between sugar carbonyl groups and amino acids (Bárcenas & Rosell, 2005). This reaction, along with the caramelization of sugars, gave the cookies made with sweet potato flour a distinct flavor. Studies by Aslam (2014) and Sukhcharn-Singh (2014) have also highlighted how these reactions can enhance sensory properties like flavor and texture in baked products containing sweet potato flour.

Table 4. 19: Sensory results of cookie samples

SAMP LE	Appeara nce	Cru st Col or	Cru mb Colo r	Aro ma	Tas te	Textu re	Tender ness	Flav or	Aft er tast e	General acceptab ility
W 100%	6 ^a	5 ^b	6 ^a	6 ^a	6 ^a	6 ^{ab}	6 ^{ab}	6 ^a	6 ^a	6 ^a
OFSP 80%	6 ^a	7 ^a	7 ^a	6 ^a	6 ^a	6 ^b	5 ^b	6 ^a	6 ^a	6 ^a
OFSP 60%	7 ^a	6 ^{ab}	7 ^a	6 ^a	6 ^a	7 ^{ab}	6 ^{ab}	6 ^a	6 ^a	6 ^a
WFSP 80%	6 ^a	6 ^{ab}	6 ^a	6 ^a	7 ^a	7 ^{ab}	7 ^a	6 ^a	6 ^a	7 ^a
WFSP 60%	6 ^a	6 ^{ab}	7 ^a	6 ^a	7 ^a	7 ^a	7 ^a	6 ^a	7 ^a	7 ^a

Mean values with different superscripts within a column are significantly different ($P < 0.05$).

Cookies made with 100% wheat flour and OFSP cookies scored similarly in general acceptability, with panelists rating them slightly lower than WFSP cookies. This may be due to the lower simple sugar content in OFSP flour, which reduced the sweetness and overall appeal to consumers. A study by Tiruneh *et al.* (2018) found that sweet potato flour's sweetness and texture played a key role in product acceptability, with sweeter formulations being preferred by panelists.

The study shows that incorporating sweet potato flour, particularly WFSP, into cookies can improve their texture and overall acceptability, especially when combined with the natural sweetness of sweet potato flour. However, color and sweetness remain important factors for consumer preference. Future studies could explore ways to enhance these qualities, such as adding additional flavorings to balance the unique properties of sweet potato flour.

4.3.3.3 Proximate analysis of cookies

The cookies made with wheat-sweet potato flour substitutions exhibited varying compositions, including ash content ranging from 1.752% to 2.770%, moisture content from 3.341% to 4.403%, crude protein from 3.88% to 7.496%, crude fiber from 1.263% to 4.476%, carbohydrates from

38.132% to 41.692%, and fat from 24.111% to 26.497% (Table 4.20). There were no significant differences in carbohydrate content between the control (100% wheat flour) and the sweet potato flour-substituted cookies; however, the ash, moisture, crude fiber, and protein contents varied significantly. These variations can be attributed to the heat generated during baking, which can influence the nutrient profile of baked goods (Tarek, Hemmat, & Emad, 2015).

Notably, protein content was highest in cookies made from 100% wheat flour and lowest in those with 80% OFSP flour. As the proportion of OFSP flour increased, the protein content decreased, reflecting the lower protein concentration in OFSP compared to wheat flour (USDA Food Data Central, 2021). Protein is an essential macronutrient providing necessary amino acids for the human body. The reduced protein levels in sweet potato-substituted cookies align with findings from Okorie and Onyeneke (2012), who linked protein loss to nitrogen depletion at elevated temperatures (165°C). Since sweet potato flours generally contain lower protein levels than other foods like beans, soybeans, and cowpeas (with a range of 24% to 34%), it is advisable for consumers to incorporate additional protein-rich foods into their diets to compensate for the lower protein content in OFSP products (Tarek, Hemmat, & Emad, 2015).

Fat content showed no significant difference across the formulations, although all products had relatively high-fat levels due to the addition of 300g of fat during formulation.

Moisture content varied significantly, with 100% wheat flour cookies having the highest moisture content and 60% WFSP cookies the lowest. Increasing OFSP flour in the recipe resulted in lower moisture levels, likely due to the differing structures and water-holding capacities of the flours. Eke-Ejiofor and Mbaka (2018) similarly reported lower moisture levels (3.0%–6.8%) in cookies made from sweet potato – wheat flour blends. The reduced moisture content in OFSP cookies could be attributed to oven drying at high temperatures, which removes moisture, enhancing the cookies' crunchiness and shelf life.

Crude fiber content varied as well, with 80% OFSP cookies exhibiting the highest levels and 100% wheat cookies the lowest. The increase in crude fiber content corresponds with the higher proportion of OFSP flour in the recipe. This finding is supported by Mais and Brennan (2008), who observed increased fiber levels with higher OFSP content in baked goods. High-fiber foods

are associated with a lower risk of conditions such as hemorrhoids, diabetes, high blood pressure, and obesity (Eliud *et al.*, 2022). Fiber adds bulk to foods and aids in digestion, preventing constipation.

Ash content also increased with higher levels of OFSP flour, with 80% OFSP cookies having the highest ash content and 100% wheat cookies the lowest. This increase can be attributed to the higher dry matter and mineral content of OFSP flour compared to wheat and WFSP flours.

Table 4. 20: Proximate results of selected cookie samples.

SAMPLE	% Ash Content	Moisture Content	Crude Protein	Crude Fibre	Carbohydrates	Fat Content
100 W	1.752 ^c	4.403 ^a	7.496 ^a	1.263 ^c	41.493 ^a	25.111 ^{ab}
80% OFSP	2.770 ^a	4.043 ^b	5.017 ^{bc}	4.476 ^a	41.692 ^a	26.497 ^a
60% OFSP	2.421 ^b	3.341 ^d	5.666 ^b	2.370 ^{bc}	41.067 ^a	24.603 ^{ab}
80% WFSP	2.158 ^b	3.840 ^c	3.888 ^d	3.487 ^{ab}	38.132 ^a	24.387 ^b
60% WFSP	2.346 ^b	4.255 ^a	4.615 ^c	2.073 ^{bc}	39.983 ^a	24.172 ^b

There are no significant differences between values in the same column with the same superscripts ($P < 0.05$).

Carbohydrate content showed no significant variation across formulations; however, 80% OFSP and 80% WFSP cookies had the highest and lowest carbohydrate content, respectively. The increase in carbohydrate content with higher OFSP flour levels can be attributed to the increase in crude fiber and ash, as carbohydrates are typically calculated by difference. As expected, carbohydrates represented the highest value in all proximate analyses, reflecting the carbohydrate-rich nature of both wheat and sweet potato flours.

In summary, the analysis of cookies made from a mixture of wheat and sweet potato flours revealed an increase in crude fiber and ash content, while moisture, protein, and carbohydrate content decreased. These changes may be due to nutrient loss resulting from exposure to high heat during baking (Tarek, Hemmat, & Emad, 2015). Nevertheless, cookies made with OFSP flour were found to contain energy, protein, minerals, fat, and fiber, all of which are essential for human health.

4.3.3.4 Vitamin A and Beta carotene content of the sweet potato cookies

The vitamin A and beta-carotene content of the cookies at 80% wheat flour substitution were 70.15 µg/g and 182.895 ppm for orange-fleshed sweet potato (OFSP) cookies, and 6.74 µg/g and 12.69 ppm for white-fleshed sweet potato (WFSP) cookies (Table 4.21). The 80% OFSP cookies had significantly higher vitamin A content compared to the other cookies, demonstrating a substantial difference in vitamin A levels. A study by Chikpah et al. (2021) reported even higher values, with beta-carotene levels of 3970 µg and vitamin A values of 305 µg at 80% wheat flour substitution. Kurabachew (2015) noted that one cookie produced in this study, weighing 61g (on a dry weight basis), provided around 800 µg of beta-carotene or 67 µg of vitamin A, contributing notably to the recommended daily allowance (RDA). Even after undergoing multiple processing steps like baking, drying, and storage, the OFSP flour successfully retained its beta-carotene, delivering a high amount of vitamin A. These findings align with those of Greene & Bowell-Benjamin (2004).

Table 4.21: Vitamin A results for selected Cookie samples.

Samples	Vitamin A (µg/ g)	Beta carotene (ppm)
80% OFSP Cookie	70.150 ± 6.451 ^a	182.895 ± 14.3 ^a
80% WFSP Cookie	6.74± 0.64 ^b	12.69±1.4 ^b

There are no significant differences between values in the same column with the same superscripts (P < 0.05).

Orange-fleshed sweet potatoes are generally recognized for their rich vitamin A content. Vitamin A (retinol) is essential for maintaining healthy skin, a strong immune system, and good vision. Incorporating OFSP flour into cookies can offer a rich source of vitamin A, making it an excellent ingredient for a nutritious snack that appeals to both children and adults.

In summary, the development and characterization of sweet potato cookies demonstrated that incorporating sweet potato flour, especially orange-fleshed sweet potato (OFSP), significantly influenced the texture, sensory properties, and nutritional profile of the cookies. Texture analysis revealed that the addition of sweet potato flour, particularly OFSP, increased cookie hardness possible due to the higher fiber and ash content in the flour. However, there were no significant differences in fracturability, indicating that the ability of the cookies to break apart remained

unchanged. Sensory evaluation highlighted that cookies with white-fleshed sweet potato (WFSP) flour were softer and had higher general acceptability, likely due to their sweeter taste and tender texture. In contrast, OFSP cookies were slightly less preferred possibly due to their poor flavor and distinctive color. Proximate analysis showed that the sweet potato flour substitutions increased fiber and ash content, while decreasing protein and moisture content. Lastly, the vitamin A and beta-carotene content was significantly higher in OFSP cookies, suggesting a nutritional advantage, particularly in addressing vitamin A deficiency.

The incorporation of sweet potato flour into cookies, especially OFSP, positively impacted the hardness and nutritional content of the cookies, with OFSP providing a substantial source of vitamin A and beta-carotene. While the sensory attributes like texture and flavor were affected by the level of sweet potato flour substitution, cookies made with WFSP flour were preferred for their softness and sweetness. These findings suggest that sweet potato flour, particularly OFSP, can be used to enhance the nutritional value of cookies, making them a healthier snack option, though further optimization of flavor and texture may be necessary for broader consumer appeal.

4.3.4 Characterization of sweet potato-based meal

4.3.4.1 Sensory analysis of sweet potato-based meal

The meals were formulated using Orange Fleshed Sweet Potato Flour (S) as the base combined with Milk Powder (M), Silver Fish Powder (F) and Egg Powder (E). The meals formulated included M3 = S:F:E (73:7:20), M2 = S:F:E (75:15:10), and M1 = S:F:E (65:15:20), all selected from design expert runs aimed at maximizing sweet potato content while ensuring sensory acceptability (see Table 4.22). The sensory characteristics of the meals made from sweet potatoes, fish, and eggs (S:F:E) were comparable regarding overall flavor (including aroma and taste), general acceptance, appearance, color, and aftertaste. The meals received general acceptability ratings between 5 and 7, with M3 being the most favored at a score of 7, while M1 was rated the least acceptable (Table 4.22).

The overall flavor and aftertaste were rated between 5 and 6, with M3 receiving the highest score and M1 (the control) the lowest. Aroma ratings ranged from 5 to 7, again with M3 rated highest at

7 and M1 rated the lowest at 5. All three formulations received a score of 6 for color and appearance. The general performance of the meals was influenced by the amount of fish and spices in the formulations, with M3 performing relatively better due to its lower silverfish content combined with added spices.

Table 4.22: Sensory results of sweet potato-based meal

SAMPLE	Appearance	Color	Aroma	Taste	Overall Flavor	After taste	General acceptability
M3	6 ^a	6 ^a	7 ^a	6 ^a	6 ^a	6 ^a	7 ^a
M2	6 ^a	6 ^a	6 ^{ab}	6 ^{ab}	6 ^{ab}	6 ^a	6 ^{ab}
M1	6 ^a	6 ^a	5 ^b	5 ^b	5 ^b	5 ^a	5 ^b

M3 = S:F:E (73:7:20); M2 = S:F:E (75:15:10); M1 = S:F:E (65:15:20)

There are no significant differences between values in the same column with the same superscripts ($P < 0.05$).

S: Sweet potato: F: Silver fish: M: Milk powder: E: Egg powder

The strong aroma and flavor of silverfish may not have been well received, as seen in M2 and M1 (the control, which contained a higher amount of silverfish powder and no spices), which were rated less favorably compared to M3. The pronounced flavor of silverfish might have been deemed undesirable by the panelists. Both M3 and M2 were spiced, which likely contributed to their overall acceptability.

In summary, the meals formulated with sweet potatoes, fish, and eggs (M1, M2, M3) exhibited similar sensory characteristics, with general acceptability ratings between 5 and 7. M3 was the most favored at a score of 7, while M1 received the lowest rating. Overall flavor and aroma ratings ranged from 5 to 6, with M3 again scoring highest. All formulations were rated equally for color and appearance at 6. The enhanced acceptability of M3 can be attributed to its lower silverfish content and the inclusion of spices, which masked the strong flavor of the fish, while M1 and M2 were less favored due to higher silverfish levels and lack of spices.

4.3.4.2 Proximate analysis of sweet potato-based meal

Table 4.23 presents the proximate composition of M3, which utilizes Naspot 13 – OFSP as the most preferred option. The nutrient content of the meal was assessed through proximate analysis, revealing that M3 contained 3.12% ash, 7.25% moisture, 15.74% crude protein, 2.83% fiber, 9.40% fat, and 40.17% carbohydrates. In comparison, Omosowone & Dairo (2015) reported a protein content of 3.78%, crude fiber content of 2.00%, moisture content of 9.70%, and fat content of 1.29%, all of which are lower than the values found in this study.

The moisture content of the meal suggests its shelf life, with higher moisture levels potentially leading to quicker spoilage due to mold growth and other factors. With a protein content of 15.74%, this meal is appropriate for individuals of all ages, particularly young children who need protein for growth and development. The elevated protein level, which has a high biological value, is primarily attributed to the substantial amounts of silverfish and eggs used. The primary contributors to the meal's energy content are fat (9%) and carbohydrates (40%), in that order.

Table 4.23: Proximate composition of sweet potato-based meal

SAMPLE	% Ash content	Moisture Content	Crude Protein	Crude fibre	Carbohydrates	Fat Content
M3 (S:F:E) 73:7:20)	3.115	7.253	15.735	2.830	40.170	9.395

There are no significant differences between values in the same column with the same superscripts ($P < 0.05$).

In summary, the development of a sweet potato-based meal incorporating orange-fleshed sweet potato flour (OFSP), milk powder, silverfish powder, and egg powder was evaluated for its sensory and proximate characteristics. Three formulations (M1, M2, M3) were prepared with varying ratios of sweet potato flour, silverfish powder, and egg powder. Sensory analysis revealed that all formulations had similar appearance and color ratings, but M3 (73% sweet potato, 7% silverfish, 20% egg) was the most preferred based on overall flavor, aroma, and general acceptability. The strong flavor of silverfish was less favored, particularly in M1 and M2, which contained higher

silverfish content and no spices, while M3 benefited from a lower silverfish ratio and added spices, enhancing its acceptability.

Proximate analysis of the most favored formulation, M3, revealed a composition of 3.12% ash, 7.25% moisture, 15.74% crude protein, 2.83% crude fiber, 9.40% fat, and 40.17% carbohydrates. This composition provides a balanced nutrient profile, particularly with its high protein content (15.74%), which is beneficial for growth and development, especially in children. The meal also provides adequate energy from carbohydrates and fats, making it a viable nutritional option.

Therefore, the sweet potato-based meal formulation, especially M3, offers a well-balanced nutrient profile with a high protein content derived from fish and eggs, making it a nutritious meal option. While the strong aroma and flavor of silverfish may not be well-received in higher concentrations, the addition of spices and lower silverfish content in M3 significantly enhanced its sensory appeal. The meal's high protein, moderate fat, and carbohydrate content make it suitable for various age groups, particularly those needing protein for growth and development. This formulation presents a promising approach to creating a nutritious and commercially viable meal using locally available ingredients like sweet potatoes, fish, and eggs hence demonstrating a viable approach for utilizing sweet potatoes by enriching them with protein sources, such as fish and eggs, thereby enhancing their commercial and industrial value.

4.3.5 Characterization of sweet potato-based porridge

4.3.5.1 Sensory analysis of sweet potato-based porridge

The sensory evaluation of sweet potato-based porridges indicated that all formulations received moderate acceptability across various sensory attributes. Appearance, color, taste, overall flavor, aftertaste, and general acceptability all received an average rating of 6 on the 9-point hedonic scale, which implies moderate liking (Table 4.24). This suggests that while all porridges were acceptable, there were subtle variations in sensory perception, particularly regarding aroma, which stood out as a key differentiator among the formulations.

The most notable difference across the formulations was in the aroma scores, which varied significantly. For example: P5 (S:F:M) = (70.2:9.8:20) and P6 (S:F:M) (75:15:10), which

contained milk powder, received the highest aroma scores (6a and 6b, respectively). These formulations likely benefited from the familiar, pleasant aroma of milk powder, which is known to enhance the aroma and flavor profile of foods (Onimawo et al., 2015). P1 (S:F:E) 75:15:10), which had higher egg powder content, received the lowest aroma rating (4b). This is likely due to the characteristic egg powder odor, which can sometimes be perceived as off-putting, especially in food products targeted at children or infants (WHO, 2020). P2 (S:F:E) 73.7:7:19.4), which had a lower silver fish content, was also rated lower in aroma (5ab), suggesting that silver fish has a noticeable impact on aroma, even in lower concentrations.

These findings align with previous research that suggests aroma is a crucial component in food acceptability, particularly in formulations for infants or children (Hassan et al., 2021). While milk powder enhanced the aroma, egg powder and silver fish potentially contributed to less favorable sensory profiles due to their distinct smells.

While aroma had the most noticeable variation, the other sensory attributes, such as taste and overall flavor, were relatively consistent across formulations. Most porridges, including P5 (S:F:M) and P6 (S:F:M), maintained a balanced flavor profile, rated at 6a for taste and flavor. The milk powder may have contributed to smoother flavor profiles, masking any harshness that might arise from the fish powder or egg powder (Michaelsen et al., 2018). Notably, P2 (S:F:E), which had a lower fish powder content, received a 5a for overall flavor. This suggests that reducing silver fish content can help balance the flavor, particularly for consumers sensitive to the strong flavor of fish. The higher levels of milk powder in P5 and P6 likely provided an overall smoother, more familiar flavor, making these porridges more palatable.

The general acceptability scores were consistently around 6, indicating moderate liking of the porridges. This demonstrates that the porridges were overall acceptable for consumption, with no formulation standing out as particularly unappealing. However, the slight variations in aroma and flavor suggest that there may be room for improvement in specific formulations to enhance consumer preference. Interestingly, P1 (S:F:E), 75:15:10), which had higher egg powder, scored lower in aroma and aftertaste (5a and 5a), which could indicate that egg powder's strong flavor and aroma, combined with no added milk powder, contributed to less favorable sensory attributes

for this formulation. On the other hand, P5 (S:F:M), with its higher milk powder content, received consistently favorable ratings for aroma and overall acceptability.

Table 4.24: Sensory results of sweet potato-based porridge

Sample	Appearance	Color	Aroma	Taste	Overall Flavor	After taste	General acceptability
P5 S:F:M (70.2:9.8:20)	6 ^a	6 ^a	6 ^a	6 ^a	6 ^a	6 ^a	6 ^a
P6 S:F:M (75:15:10)	6 ^a	6 ^a	6 ^b	6 ^a	6 ^a	5 ^a	6 ^a
P2 S:F:E (73.7:7:19.4)	6 ^a	6 ^a	5 ^{ab}	6 ^a	5 ^a	5 ^a	6 ^a
P4 S:F:M (65:15:20)	6 ^a	6 ^a	6 ^{ab}	6 ^a	6 ^a	6 ^a	6 ^a
P1 S:F:E (75:15:10)	6 ^a	6 ^a	4 ^b	6 ^a	5 ^a	5 ^a	6 ^a
P3 S:F:E (65:15:20)	6 ^a	6 ^a	5 ^{ab}	6 ^a	6 ^a	5 ^a	6 ^a
P value	0.974	0.995	0.005	0.947	0.587	0.176	0.391

There is no significant difference between values in the same column with the same superscripts.

S: Sweet potato: F: Silver fish: M: Milk powder: E: Egg powder

All the formulations were nutrient-dense, especially in protein, which is essential for growth and development, particularly in infants (WHO, 2020). The fish powder is a source of omega-3 fatty acids, while the milk powder and egg powder offer important calcium, vitamins, and proteins. Sweet potatoes, the base ingredient, rich in fiber and carbohydrates, which is beneficial for energy, and the formulations were designed to provide a balanced macronutrient profile. The combination of sweet potato, fish, and milk/egg powders creates a food that is well-suited to meeting the energy and protein needs of infants, supporting both growth and development.

In conclusion, the sensory evaluation of the sweet potato-based porridges demonstrated that both S:F:M and S:F:E formulations were moderately liked by consumers. The addition of milk powder generally enhanced the aroma and overall flavor, making the porridges more acceptable, while egg powder and fish powder contributed to less favorable sensory results when present in higher concentrations. These findings suggest that future product formulations could benefit from a balanced use of ingredients, particularly milk powder, to optimize flavor and aroma while maintaining nutritional value. Further research may focus on optimizing ingredient ratios to further improve sensory characteristics and long-term consumer acceptability.

4.3.5.2 Proximate composition of sweet potato-based porridge

The proximate composition analysis of Porridge P2 (S:F:E), 73.7:7:19.4), a sweet potato-based formulation enriched with fish powder and egg powder, reveals significant nutritional characteristics (Table 4.25) that highlight its potential as a complementary food for infants and young children.

Table 4.25: Proximate values of sweet potato porridge product

SAMPLE	% Ash content	Moisture Content	Crude Protein	Crude fibre	Carbohydrates	Fat Content
P2 S:F:E (73.7:7:19.4)	3.559	7.116	14.5	2.931	46.911	7.146

There are no significant differences between values in the same column with the same superscripts ($P < 0.05$).

S: sweet potato: F: Silver fish: E: Egg powder

The formulation demonstrated the following nutritional composition: 3.56% ash, 7.12% moisture, 14.5% crude protein, 2.93% crude fiber, 7.15% fat, and 46.91% carbohydrates (Table 4.25). These values underscore the porridge's capacity to provide essential nutrients, aligning with its intended role in meeting the energy and developmental needs of growing children.

The high carbohydrate content of 46.91% is particularly noteworthy as carbohydrates are the primary source of energy for infants and young children, whose energy needs are relatively high compared to their body weight (Dewey, 2013). The carbohydrate-rich composition of this porridge suggests that it could serve as an effective energy source, making it suitable as a complementary food to support the rapid growth and development of children, especially during the weaning phase. Carbohydrates from sweet potato flour, a key ingredient in this formulation, contribute not only to energy but also to dietary fiber, which supports digestive health (Haug & Lantzsch, 1983). The high carbohydrate content aligns with findings from previous studies that emphasize the importance of energy-dense foods in weaning diets, particularly in regions where under-nutrition is prevalent (Kikafunda *et al.*, 2009). The energy-dense nature of the porridge also makes it an ideal option for meeting the high-energy needs of children in developing countries where malnutrition remains a major concern (WHO, 2020).

The 14.5% crude protein content is another highlight of this formulation. Proteins are vital for the growth, development, and repair of tissues, and they play an essential role in supporting the immune system, enzyme function, and the synthesis of hormones (Michaelsen *et al.*, 2018). For young children, adequate protein intake is crucial, particularly for tissue growth, organ development, and immune function. The high protein content in this formulation is largely attributed to the inclusion of egg powder and fish powder, both of which are rich in high-quality proteins with all the essential amino acids required for infant development. The amino acid profile from fish, which includes omega-3 fatty acids (e.g., DHA and EPA), is especially beneficial for brain development (Gibson *et al.*, 2011). This, combined with the high biological value of egg proteins, supports the role of this porridge in promoting healthy growth in children (Aydin *et al.*, 2018).

The fat content of 7.15% contributes to high energy of the porridge. Fat is an essential macronutrient, providing a concentrated source of energy and essential fatty acids. Infants, due to their high growth rates, require higher energy intake in relation to their body weight compared to adults. Fat in this porridge comes from both the egg powder and fish powder, both of which are also sources of omega-3 fatty acids, contributing to the overall nutritional quality of the porridge by supporting brain and eye development (Innis, 2007). The 7.15% fat content in this formulation is in line with the nutritional guidelines for complementary foods for infants, which emphasize the importance of providing adequate energy from fats for growth and development, particularly when transitioning from breast milk to solid foods (Dewey, 2013).

The moisture content of 7.12% in this porridge is within acceptable limits for complementary foods. A relatively low moisture content is essential for prolonging shelf life, as high moisture levels can lead to spoilage and mold growth (DeWitt & Dahl, 2015). Moisture content between 6% to 8% is typical for well-prepared infant foods, ensuring both safety and optimal storage conditions (Haile *et al.*, 2015). The moisture level in P2 is therefore well-balanced for practical use as a complementary food, facilitating longer storage without compromising safety.

The ash content (3.56%) provides an estimate of the mineral content in the porridge. Ash content is a reflection of the inorganic matter remaining after combustion, which includes essential minerals such as calcium, magnesium, potassium, and phosphorus. These minerals are vital for

bone development and physiological processes in young children. Sweet potato flour, one of the main ingredients, has high potassium content, critical for maintaining fluid balance and proper muscle function (Rao *et al.*, 2015). The ash content here is comparable to values found in other complementary foods, ensuring an adequate supply of minerals.

The 2.93% crude fiber content in this porridge contributes to digestive health by supporting regular bowel movements and preventing constipation, which is common among infants transitioning to solid foods. Dietary fiber also plays a role in modulating blood sugar levels, which can aid in energy regulation (Slavin, 2013). Fiber from sweet potato also adds to the satiety of the porridge, making it a filling meal for growing children (Haug & Lantzsch, 1983).

Comparing these results to other complementary food formulations, such as those reported by Darshane (2021), we observe some differences in composition, particularly regarding protein and carbohydrate content. For example, Darshane reported higher protein (22.5%) and carbohydrate (65.66%) values, but with lower moisture (6.33%), ash (2.48%), and fat (2.83%) contents. These differences may arise from variations in ingredient types and ratios, processing methods, or the source of ingredients (such as the specific types of fish or eggs used). Similarly, Haile *et al.* (2015) observed moisture levels between 4-8% and protein content ranging from 4-8%, which indicates that the protein and fat levels in this formulation are higher, likely due to the fish powder and egg powder contributions.

In conclusion, the proximate composition of the sweet potato-based porridge (S:F:E), 73.7:7:19.4) reveals that this formulation is rich in energy, protein, and essential nutrients, making it suitable as a complementary food for infants and young children. The high carbohydrate and protein content support energy needs and growth, while the fat content enhances the energy density required for children with high metabolic rates. Additionally, the moderate fiber content promotes digestive health, and the ash content reflects the presence of essential minerals. Compared to other formulations, this porridge formulation stands out in terms of its nutritional richness, especially in protein and fat content, which can contribute to improved nutritional outcomes in vulnerable populations. Given these attributes, the porridge has the potential to play a critical role in preventing malnutrition and promoting healthy growth and development in young children.

4.4 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was performed using XLSTAT 2019 to explore relationships among the pasting properties, starch yield, dry matter, water holding capacity (WHC), swelling power of sweet potatoes, and the physical, sensory, and proximate composition of composite bread, cakes, and cookies. The analysis produced five principal components that explained a total of 77.2% of the variance. The first principal component (PC1) explained 52.55% of the variance, distinguishing Orange-fleshed Sweet Potato (OFSP) products from White-fleshed Sweet Potato (WFSP) products, while the second principal component (PC2) accounted for 24.65% of the variance, focusing on appearance and sensory qualities.

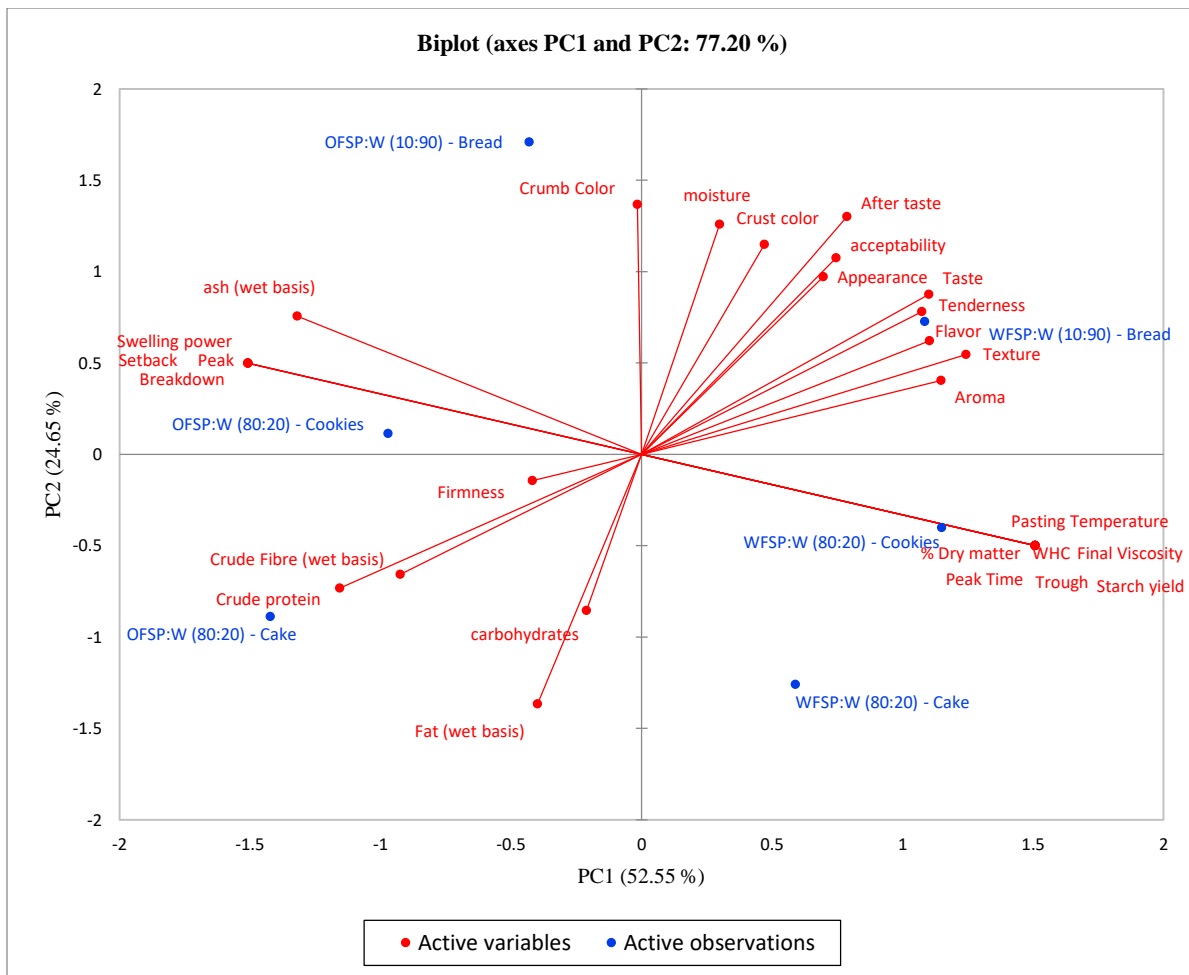


Figure 4.1: Biplot showing the relationship between properties of sweet potato varieties and proximate composition, physical and sensory properties of the composite bread, cakes and cookies. OFSP – Orange fleshed sweet potato; WFSP – white fleshed sweet potato; W – wheat; WHC – water holding capacity.

Key Observations by Principal Component:

F1 (Starch and Textural Properties): This component is positively correlated with WHC, % dry matter, starch yield, and several viscosity-related measures (e.g., trough, final viscosity, peak time, pasting temperature). It is primarily associated with textural properties and starch characteristics of the products. Variables like firmness, appearance, taste, texture, aroma, flavour, and tenderness are also positively loaded on F1. These characteristics are more prominent in bread and cookies made with WFSP, while OFSP products show negative loadings on these attributes.

F2 (Moisture, Appearance, and Sensory Quality): This component captures attributes related to appearance, crust color, crumb color, acceptability, and moisture content. Positive loadings on moisture and crust color suggest that this component is strongly associated with the visual appeal and freshness of the products. It also highlights aftertaste, flavour, and texture. These qualities are more pronounced in bread products containing OFSP, while fat and carbohydrate content negatively load on this component, indicating that cakes with OFSP are associated with these attributes.

F3 (Nutritional Content): F3 represents the nutritional composition of the products, particularly fat, carbohydrates, and crude fiber. This factor is positively correlated with energy-dense attributes, making it important for assessing the caloric content of the products. Crude protein and crude fiber are also positively loaded here, highlighting their nutritional relevance.

F4 (Sensory Qualities - Taste, Aroma, and Tenderness): This component focuses on sensory attributes like crumb color, aroma, taste, tenderness, and acceptability. These attributes are associated with the eating experience and consumer satisfaction, particularly influencing flavor and overall product acceptability. Products with OFSP, such as bread, show a stronger association with this component.

F5 (Hydration and Flavor Profiles): F5 captures moisture, firmness, and flavour profiles, with positive correlations between these attributes. It reflects the overall hydration quality and mouthfeel, contributing to the enjoyment of the food products.

Factor Scores Interpretation:

The factor scores table shows how each product type is positioned on each principal component (F1 to F5). This helps to understand how product formulations relate to the different factors identified in the analysis.

WFSP : W (10:90) - Bread: This product has high positive scores on F1, indicating it is characterized by starch-based properties and good textural qualities such as firmness, water holding capacity, and viscosity. Positive loadings on moisture content and appearance also highlight its sensory appeal.

OFSP : W (10:90) - Bread: This bread formulation is closely associated with F2, emphasizing moisture, crust color, and sensory properties like taste and aroma. The strong positive score on F4 indicates that taste and flavor are critical characteristics for this product.

WFSP : W (80:20) - Cake: The negative score on F1 suggests this cake has lower starch-based properties compared to breads and cookies. It is more closely associated with F3, indicating it is energy-dense with higher levels of fat, carbohydrates, and crude fiber.

OFSP : W (80:20) - Cake: This formulation shows strong negative scores on F1, indicating a lower association with starch and textural properties. The low scores on F2 also suggest a reduced sensory appeal, with poor moisture and appearance.

WFSP : W (80:20) - Cookies: WFSP cookies are characterized by strong positive scores on F1 and F3, indicating that they are rich in starch and fat, contributing to firmness and energy density.

OFSP : W (80:20) - Cookies: The OFSP cookies exhibit negative scores on F1 but a moderate positive score on F3, indicating lower starch and textural properties compared to WFSP cookies. However, they remain energy-dense due to their fat and carbohydrate content.

In summary, PCA analysis revealed that the relationships among the physical, sensory, and proximate properties of bread, cakes, and cookies made from WFSP and OFSP can be grouped into five principal components. These components describe the key attributes that define product differences, such as starch-based properties (F1), moisture and appearance (F2), nutritional composition (F3), and sensory quality (F4 and F5). The factor scores demonstrated that WFSP-based products tend to have better textural qualities, moisture content, and starch yield, while OFSP-based products are more closely associated with sensory properties, moisture, and aesthetic qualities.

Products such as bread and cookies made from WFSP show strong associations with starch-based properties and energy density, whereas OFSP-based products excel in sensory appeal, including moisture, flavour, and appearance. The PCA provided a clear understanding of how variations in sweet potato type and formulation affect the texture, nutritional content, and sensory attributes of the food products.

The PCA analysis successfully elucidated the underlying relationships between the sensory, textural, and nutritional characteristics of the sweet potato-based products. It highlighted the significant differences between WFSP and OFSP formulations, with WFSP products generally exhibiting better starch-based properties and textural quality, while OFSP products were more associated with moisture content, flavour, and appearance. This analysis is invaluable for guiding the formulation of sweet potato-based baked goods, enabling the development of products with tailored sensory profiles and nutritional compositions to meet specific consumer preferences and dietary needs.

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General Discussion of the key findings

The characterization of selected Ugandan sweet potato varieties, including their starch properties and their use in various food products, revealed significant variation in their physicochemical, nutritional, and sensory attributes. This study highlighted the potential of sweet potato varieties to contribute to food security and nutrition through their application in products like bread, cakes, cookies, and porridges.

Variety and Nutritional Value: The study demonstrated that skin and pulp color in Ugandan sweet potato varieties are influenced by environmental and genetic factors. Orange-fleshed varieties, such as Naspot 13, have high β -carotene content, making them valuable for addressing vitamin A deficiencies. These varieties also exhibit high levels of nutritional components, including fiber and carbohydrates, making them suitable for use in energy-dense products.

Starch Properties: Significant differences in starch yield, water holding capacity, swelling power, and pasting properties were observed across sweet potato varieties. Local varieties generally exhibited higher yields of starch with more stable pasting properties, making them ideal for certain food applications. Moreover, starch from varieties like *Nakakande* demonstrated high levels of resistant starch, which can improve digestive health and prolong satiety.

Processing and Product Development: The addition of sweet potato flour into wheat-based products such as bread, cookies and cakes, significantly affected their texture, moisture retention, and sensory properties. While increase in amount of sweet potato flour led to firmer textures and reduced sensory acceptance, moderate inclusion (up to 10-12.5%) offered a good balance between improving nutritional content and maintaining consumer preferences. Particularly, sweet potato flour from orange-fleshed varieties offered substantial nutritional advantages, including higher fiber and β -carotene content.

Sensory and Consumer Acceptance: Sensory evaluation across different product formulations highlighted the impact of sweet potato flour substitution on flavor, texture, and overall

acceptability. While orange-fleshed sweet potato (OFSP) flour contributed to higher nutritional content, it often resulted in reduced consumer acceptability due to flavor and texture changes. This underscores the need for balanced formulations to optimize sensory appeal while maintaining nutritional benefits.

Meal Formulations: The incorporation of sweet potato flour in meal formulations with ingredients like fish and eggs was well-received when balanced with spices to mask strong flavors. These formulations showed potential in providing high-protein, nutrient-dense meals suitable for vulnerable populations, including children.

Principal Component Analysis (PCA): PCA analysis revealed the relationships among physical, sensory, and proximate properties, distinguishing the characteristics of bread, cakes, and cookies made from white-fleshed sweet potato (WFSP) and orange-fleshed sweet potato (OFSP). This analysis emphasized that WFSP-based products excelled in texture and starch-based properties, while OFSP-based products excelled in sensory attributes like flavor and appearance, which can be crucial for developing tailored sweet potato-based food products.

5.2 Conclusion

The study showed that the beta carotene and vitamin A levels in orange fleshed sweet potatoes was high hence can be used for product development. Furthermore the dry matter content in the white fleshed sweet potatoes was high making the sweet potatoes a good raw material for processing.

Sweet potato flour substitution in wheat-based products affects texture and sensory qualities, low levels of wheat substitution can balance nutritional enhancement with consumer acceptability.

Sweet potato flour, particularly from orange-fleshed varieties, is suitable for improving the nutritional profile of bakery products, snacks, and meals, thus offering a sustainable alternative to traditional wheat flour, particularly in regions facing rising wheat costs and micronutrient deficiencies. Furthermore, optimization of product formulation can be used to sweet potato flour inclusion needs while meeting specific sensory and nutritional requirements.

5.2 Recommendations

Based on results of the study, the following are recommended;

A combination of wheat flour sweet potato (WFSP) and orange-fleshed sweet potato (OFSP) flour should be used in cake and cookie formulations at 60-80% and bread at 25-30% to achieve an optimal balance between texture and nutritional content.

Sweet potato flour, combined with ingredients like fish and milk powder, should be incorporated into porridge and meal formulations to enhance their nutritional profile. Preferably the formulation of 73:7:20 for sweet potato, fish and milk to be used to provide essential macronutrients, making them suitable for all age groups, particularly infants and children. This can help address nutritional gaps in the diet, especially in vulnerable populations.

More research should be carried out to assess the shelf stability of sweet potato-based products under various storage conditions, ensuring that the products remain of high quality without spoilage.

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APPENDICES

Factor loading table

	F1	F2	F3	F4	F5
WHC	0.942	-0.312	-0.069	-0.102	0.035
% Dry matter	0.942	-0.312	-0.069	-0.102	0.035
Starch yield	0.942	-0.312	-0.069	-0.102	0.035
Swelling power	-0.942	0.312	0.069	0.102	-0.035
Peak	-0.942	0.312	0.069	0.102	-0.035
Trough	0.942	-0.312	-0.069	-0.102	0.035
Breakdown	-0.942	0.312	0.069	0.102	-0.035
Final Viscosity	0.942	-0.312	-0.069	-0.102	0.035
Setback	-0.942	0.312	0.069	0.102	-0.035
Peak Time	0.942	-0.312	-0.069	-0.102	0.035
Pasting Temperature	0.942	-0.312	-0.069	-0.102	0.035
Firmness	-0.261	-0.090	0.953	-0.100	0.072
Appearance	0.435	0.607	0.611	-0.257	-0.055
Crust color	0.294	0.718	0.422	-0.460	-0.092
Crumb Color	-0.010	0.854	0.149	-0.481	0.131
Aroma	0.717	0.253	0.645	-0.079	0.026
Taste	0.688	0.546	-0.051	0.380	0.286
Texture	0.776	0.341	0.418	0.297	-0.133
Tenderness	0.671	0.488	-0.165	0.460	-0.270
Flavor	0.689	0.388	0.597	-0.080	-0.106
After taste	0.491	0.813	-0.150	0.244	0.124
acceptability	0.466	0.672	-0.072	0.572	-0.012
moisture	0.187	0.786	-0.533	-0.247	0.044
ash (wet basis)	-0.824	0.472	0.059	-0.293	0.099
Fat (wet basis)	-0.249	-0.854	0.422	0.160	-0.075
Crude protein	-0.722	-0.458	-0.394	-0.326	-0.087
Crude Fibre (wet basis)	-0.577	-0.410	0.504	0.299	0.394
carbohydrates	-0.132	-0.533	0.814	0.157	-0.102

Factor score

	F1	F2	F3	F4	F5
WFSP:W (10:90) - Bread	4.160	1.910	-1.092	-1.677	0.810
	-				
OFSP:W (10:90) - Bread	1.652	4.490	-1.181	0.873	-0.707
WFSP:W (80:20) - Cake	2.263	-3.310	-0.866	-1.016	-1.009
	-				
OFSP:W (80:20) - Cake	5.457	-2.332	-2.156	0.587	0.615
WFSP:W (80:20) - Cookies	4.412	-1.055	1.539	2.275	0.269
	-				
OFSP:W (80:20) - Cookies	3.727	0.298	3.756	-1.042	0.023

Consumer acceptability Sensory evaluation ballot

Nine-point hedonic scale

Panelist No. _____ Age..... Gender.....

You are provided with 3 samples of bread. Please observe, smell and taste each sample; and record your liking of the samples on the scale of 1 to 9 by placing your score in the box next to the sensory parameter under each sample in the table below. Please evaluate the products in the order in which they are presented. Use the water provided to rinse your mouth before and after tasting each sample and between samples.

ANSWER ALL QUESTIONS. We want to know what you think!! If you have any questions, please ask the study coordinators.

Score the products using hedonic scale below	
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Quality attributes	Sample No.						
Appearance							
Color							
Aroma							
Taste							
Mouth feel							
Overall acceptability							

Which sample (only one) would you buy and why?

.....

.....

General comments:

.....

.....

Thank you for participating in this exercise

Pictures showing different cookie substitutions





Pictures showing different cake substitutions;



