

Effects of orange-fleshed sweet potato (*Ipomoea batatas*)-Bambara groundnut (*Vigna subterranea*) composite flour on quality properties of pasta

By

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DECLARATION

I, Makhuvha Makgwatla Consolerlia, Student No. 11612361, hereby declare that the proposal for Master of Science degree in Food Science and Technology titled, “**Effect of orange fleshed sweet potato (*Ipomoea batatas*)-Bambara groundnut (*Vigna subterranea*) composite flour on quality properties of pasta**”, submitted by me to the Department of Food Science and Technology at University of Venda, has not previously been submitted for a degree at this or any other University. This is my own work in design, execution and that all reference materials and work of others contained herein have been dully acknowledged.



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05 September 2023

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DEDICATION

This work is dedicated to my sister, Metse Makhuvha, who has been with me no matter what happened. She supported me, believed in me, and inspired me during years of study. I also dedicate the study to my late Father Mangala Adam Makhuvha and my late Mother Molatelo Philliapine Makhuvha. Sadly, my parents died a few years ago and would have been delighted and happy for me.

ABSTRACT

Non-wheat flours are being used to partially replace wheat flour. This is expected to increase the utilization of local raw materials while easing demand for wheat. The goal of the study was to investigate how composite flour derived from orange fleshed sweet potato (*Ipomoea batatas* (L.) LAM) and Bambara groundnut (*Vigna subterranean* (L.) Verdc) affects the quality of pasta while also improving its nutritional characteristics. Orange fleshed sweet potatoes (OFSP) were produced at the Agricultural Research Council Roodeplaat Campus in Pretoria, and Bambara groundnuts were sourced from the Thohoyandou area, Vhembe district in South Africa. The OFSP were peeled, sliced, dried for 10 hours at 60°C using a hot air oven drier and ground into flour. Bambara groundnut flour was made by soaking the seeds in water for 24 hours, dehulling them, drying them in an oven dryer for 24 hours at 60°C, and they were then ground into flour. The pasta was produced from a mixture of semolina, OFSP and Bambara groundnut flours in the ratios 90:5:5; 70:15:15 and 50:25:25. The functional and physicochemical properties of the pasta, as well as its cooking and sensory qualities were investigated. The samples were analyzed in triplicate using a randomized complete block design. The data was subjected to ANOVA and the Duncan multiple range test was used to differentiate significant means. Pasta produced from composite flour significantly affected the proximate composition and cooking quality compared to 100% wheat pasta. Good nutritional quality pasta was obtained from the blend of 50:25:25 semolina, OFSP and Bambara groundnut flour which exhibited a high value of protein (9.73%), ash (4.38%) and fibre (2.27%), vitamin A (1.95mg/100g) and vitamin C (8.93mg/100g) content. The pasta enhanced with composite flour of 70:15:15 semolina, OFSP and Bambara groundnut was mostly preferred during consumer acceptability testing compared to the pasta produced from 90:5:5 semolina, OFSP and Bambara groundnut flour; 50:25:25 semolina, OFSP and Bambara groundnut flour and 100% wheat.

Key words: Orange fleshed sweet potato, Bambara groundnut, Processing, Pasta, Functional, Physicochemical, Sensory

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ABBREVIATIONS

AACC	American Association of Cereal Chemists
AOAC	Association of Official Analytical Chemists
BD	Bulk density
OAC	Oil absorption capacity
OFSP	Orange fleshed sweet potato
SI	Swelling Index
WAC	Water absorption capacity

CHAPTER 1: INTRODUCTION

1.1 Background

Soon, world agriculture will struggle to meet demand for wheat, especially as global consumption rises (Grote *et al.*, 2021). An estimated 35% of the world population depends on wheat as their primary crop. It is eaten in the form of bakery and confectionary goods, pasta, breakfast cereals, and bread (Abdullahi, 2021). According to Gebreselassie *et al.*, (2017), the supply of wheat is expected to grow by 73% (from 2.6 million in 2010 to 4.5 million tons in 2030), whereas demand is expected to increase by 90%. Wheat demand growth will rise as a result of a number of reasons, including urbanization, the increase of agro-processors, and rising household income in the future (Gebreselassie *et al.*, 2017).

Furthermore, several issues such as climate change, lack of fresh water, soil erosion, pollution, as well as the conversion of agricultural land to other purposes may imperil the ability to meet demand for wheat. As the market for wheat products grows, more local raw resources are replacing wheat flour (Trisna *et al.*, 2020).

South Africans have increased their consumption of wheat in the last ten years. Wheat demand was expected to be 3.33 million metric tons in the 2019/2020 marketing year. Due to a decline in output in the Western Cape, wheat and wheat products imports were expected to reach 2.0 million tons in year 2019/2020. Over 1.6 million tons of wheat products were expected to be imported in the season of 2020/2021 year (Van Antwerpen *et al.*, 2021).

Processing of composite flour would be advantageous in developing countries like South Africa as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour (Hugo *et al.*, 2000; Hasmadiet *et al.*, 2020). Composite flour produced from legumes and tubers are higher in protein content and calorific value (Nwadi *et al.*, 2020). The diet, which is high in complex carbohydrates, as well as legumes like Bambara groundnut and vegetables like orange-fleshed sweet potato, can lower the risk of diseases like diabetes, hypertension, cardiovascular diseases and obesity (Oniang'o *et al.*, 2003; Reungmanee-paitoon, 2009; Tan *et al.*, 2020).

The Bambara groundnut grows in sub-Saharan Africa, as well as regions of Latin America and Asia (Udeh *et al.*, 2020). It is the third most important legume after groundnut (*Arachis*

hypogea) and cowpea (*Vigna unguiculata*) (Adebowale *et al.*, 2011; Messina *et al.*, 2022; Ramatsetse *et al.*, 2023). It is high in protein, carbohydrates, and phosphorus.

The seed grain contains a healthy amount of iron and calcium, as well as an excellent balance of vital amino acids; with a high proportion of lysine and methionine (Kaptso *et al.*, 2015). Kaptso *et al.*, (2015), also states that Bambara groundnut protein contains more critical amino acid methionine than other grain legumes while the oil content is less than half that of other grain legumes.

In many parts of the world, the orange fleshed sweet potato (OFSP) is a major crop (Low and Thiele, 2020). It is the world's seventh-largest food crop and the fourth-largest in tropical countries (International Potato Center, 2017). Sebben *et al.*, (2017), indicate that starchy crops such as sweet potato are a staple meal in some African countries (Uganda, Rwanda, and Burundi), but in others (Malawi, Angola, Mozambique, and the Democratic Republic of Congo) they are utilized as an additional or food security crop.

The crop contains a high proportion of macro- and micronutrients, including significant amounts of vitamin A, moderate amounts of vitamin C, vitamin B complex (vitamins B1, B2, B5, and B6), and folic acid, as well as adequate amounts of vitamin E and the minerals iron, zinc, and magnesium (Laveriano-Santos *et al.*, 2022). In South Africa and other developing countries, the OFSP root can be turned into flour which could be used to supplement micronutrients in porridge, bread, traditional doughnuts, snacks, and cakes for target consumers (Dereje *et al.*, 2020).

OFSP can also be processed into pasta, which is defined as the product obtained by extrusion or lamination, and successive drying of dough made exclusively of durum wheat semolina and water, sometimes followed by drying (Balestra *et al.*, 2010; Kolawole *et al.*, 2020). Pasta is a low-calorie, low-fat, cholesterol-free, and sodium-free food. Thiamine, iron, riboflavin, and niacin are all found in abundance in pasta (Savita *et al.*, 2013; Tetrycz *et al.*, 2023). It also contains considerable amounts of complex carbohydrates, proteins, B-vitamins, and amino acids, making it a good source of energy for both the body and the brain (Fuad and Prabhasankar, 2010; Savita *et al.*, 2013).

Pasta is the world's second most consumed wheat-derived staple meal, after bread; thus, improving the quality of pasta by adding other components is crucial (Savita *et al.*, 2013). Pasta is popular due to convenience, versatility, palatability and relative long shelf life (Baah *et al.*, 2022). In Italy, the potato-based pasta is known as gnocchi, and it can be made at home or in a

factory. Traditional homemade pasta is consumed on the same day it is prepared, but industrially produced non-dried pasta is vacuum-packed in polyethylene and kept refrigerated (Savita *et al.*, 2013). In contrast to fresh pasta, industrial dried pasta is dried at a low temperature for a number of days until all the moisture has evaporated, enabling it to be preserved for nearly an infinite amount of time. The goal of drying is to reduce the moisture content of pasta from about 31% to 12–13% so that the final product will be firm, maintain its shape, and store without getting spoiled (Carpentieri *et al.*, 2022).

Modern and active lifestyle leads to the need to industrially produce pasta by saving both time and money, even in the household. For this reason, preparations of ready to use pasta are increasing (Balestra *et al.*, 2010; Bresciani *et al.*, 2022). Thus, this research was conducted to determine the functional, physicochemical, cooking qualities and sensory characteristics as descriptive quality parameters of pasta produced from OFSP and Bambara groundnut flour.

1.2 Problem statement

Pasta made from durum wheat is consumed worldwide and it is a healthy product with a good texture, cooking attributes and it is also convenient; however due to the desire for functional foods from health-conscious consumers over the past two decades, there has been a lot of research done on how to increase the nutritional content of pasta by incorporating nonconventional ingredients. Because of the prevalence of gluten-related illnesses, wheat allergy, non-celiac gluten sensitivity, malnutrition, and vitamin A deficiency among low-income people and preschool children, nutrition is becoming a serious concern.

The fortification of pasta with various vitamins and protein source such as OFSP and Bambara groundnuts and the elimination or reduction of wheat in the human diet would be advantageous in enhancing the nutritional value of pasta, will benefit the health of consumers and improve the quality of pasta.

Furthermore, due to the low protein content of OFSP but abundance of provitamin A, there is a need to add a protein source such as Bambara groundnut to enhance the nutritive quality of the pasta product through addition of Bambara groundnut, which is rich in protein (lysine and methionine). Therefore, there is a need to develop a pasta product of high nutritional value which is also affordable, readily available, palatable and shelf-stable from orange-fleshed sweet potato and Bambara groundnut.

1.3 Objectives

Main objectives

The overall objective of the study was to determine how composite flour derived from orange fleshed sweet potato (*Ipomoea batatas* (L.) LAM) and Bambara groundnut (*Vigna subterranean* (L.) Verdc) affected the functional, cooking and sensory properties of pasta while also improving its nutritional characteristics towards development of novel food items from roots and legume crops.

Specific objectives

- a) To analyze how the nutritional properties (protein, carbohydrates, fat, fiber, moisture, ash, vitamin A, and vitamin C) of orange-fleshed sweet potato and Bambara groundnut composite flour affect pasta nutrition.
- b) To examine how OFSP and Bambara groundnut composite flour affects the functional qualities of pasta (swelling power, bulk density, water and oil absorption).
- c) To determine how OFSP and Bambara groundnut composite flour affects the cooking attributes of pasta (texture, cooking loss, optimum cooking time, and colour).
- d) To establish how OFSP and Bambara groundnut composite flour affects the sensory acceptability of pasta.

1.4 Hypothesis

The addition of OFSP and Bambara groundnut composite flour to pasta will improve its nutritional, functional, and sensory qualities.

1.5 Justification

Several developing countries have supported research into the practicality of replacing wheat flour with locally available flour alternatives (Abdelghafor *et al.*, 2011). Hasmadi *et al.*, (2020) claim that using composite flour in various food products would be cost-effective because wheat imports may be reduced or even eliminated. Furthermore, instead of wheat, domestically grown foods might be used to meet the need for bread and pasta products (Jisha and Rosell, 2008).

Products produced from the composite flour supplemented with β -carotene such as OFSP, yellow maize, yellow cassava and golden rice increases the nutritional value and the appearance of the products (Baah *et al.*, 2022). Apart from being a good source of calories and other nutrients,

wheat is considered have low amount of protein as it is deficient in essential amino acids such as lysine, leucine, arginine and methionine (Dhingra and Jood, 2002; Julianti *et al.*, 2017; Moreno-Valdespino *et al.*, 2020).

Wheat flour can be supplemented by locally grown crops such as OFSP and legumes such as Bambara groundnuts which are rich in vitamin A and protein to boost its nutritional quality. Therefore, research and improvement efforts are needed to explore the benefits of OFSP and Bambara groundnut to increase agricultural production, nutritional bioavailability and the improvement of nutritional quality through processing.

CHAPTER 2: LITERATURE REVIEW

2.1 Composite flour

Composite flour is a mixture of flours, starches, and other ingredients used to completely or partially replace wheat flour in products utilizing wheat (Hasmadi *et al.*, 2020; Noorfarahzilah *et al.*, 2014). Similarly, Abdel-Kader (2000) defines composite flour as a mixture of starch-rich tubers (e.g. cassava, yam, sweet potato) and/or protein-rich flours (e.g. soy, peanut, and Bambara groundnut) and/or cereals (e.g. maize, rice, millet, buckwheat) with or without wheat flour. Composite flour is used in a variety of bakery and pastry goods, triggering a spike in research into the effects of different types of materials used to create flour on their physicochemical and functional properties (Sulieman *et al.*, 2019).

Ready-mixed flours and composite flours differ in that; ready-mixed flours comprise all of the non-perishable elements in a recipe for a specific baked food, whereas composite flours are just a mixture of diverse vegetable flours high in starch or protein, with or without wheat flour (Noorfarahzilah *et al.*, 2014). Composite flour is used in poor countries to minimize wheat flour imports and to promote the consumption of locally farmed produce (Hugo *et al.*, 2000; Hasmadi *et al.*, 2020). According to the FAO (2006), using composite flour in a wide range of food products would be cost-effective if wheat imports are substantially reduced, and that demand for bread and pastry products could be met by the use of domestically grown products instead of wheat (Nwanekezi *et al.*, 2013).

Composite flours are beneficial because shortages of important amino acids in wheat flour are replaced from additional sources (Ferial *et al.*, 2011). Bamigbola, (2016) argues that the addition of the composite flours in wheat flour will improve consumer health due to the increase of protein, vitamins, fibre and mineral contents in products produced from wheat flour. Other researchers have recommended that when choosing components for composite flour blends, materials that are readily available, culturally acceptable, and have a higher nutritious potential should be used (Bolarinwa *et al.*, 2015; Barber and Okoli, 2010).

The use of composite flour has numerous benefits, one of which is that it is essential in addressing vitamin deficiencies. It saves hard currency; promote high yielding local plant species and enhances overall use of domestic agriculture (Bibiana *et al.*, 2014; Malavi *et al.*, 2022). According to Mubaiwa *et al.*, (2017), composite flours are advantageous in the sense that inherent deficiencies of essential amino acids in wheat flour (lysine, tryptophan and threonine) are supplemented from other sources.

The research studies have been conducted to encourage the use of composite flours, which replace some of the wheat flour used in pasta and bread with flour from locally grown crops and high protein seeds. This reduces the need for imported wheat and results in products that are protein-enriched (Giami *et al.*, 2004; Idolo, 2011; Kumar *et al.*, 2020).

In poor communities, particularly in sub-Saharan Africa, micronutrient deficiency continues to be a major nutritional concern, with children and women being the most at risk (Bain *et al.*, 2013). Composite flours with greater nutritional qualities would be widely desired in nations where malnutrition is a major issue, particularly for children (Baah *et al.*, 2022). Addition of various proportions of OFSP and Bambara groundnut flour in wheat flour can increase the nutritive values in terms of protein, fibre and carotenoids. Additionally, lowering the gluten level in food products helps to prevent celiac disease (Ijah *et al.*, 2014).

In recent years, several reports have indicated that the phytochemicals in sweet potatoes displayed antioxidative or radical scavenging activity and exerted several health promoting functions in humans (Konczak-Islam *et al.*, 2003; Rabah *et al.*, 2004; Malhotra *et al.*, 2022). Increasing dietary antioxidants intake may help to maintain an adequate antioxidant status, defined as the balance between antioxidants and oxidants in a living organism (Reungmaneepaitoon, 2009; Malhotra *et al.*, 2022).

Bibiana *et al.*, (2014) state that there is interest in increasing consumption of nutritious low-glycaemic-index foods, especially in the context of a projected alarming rise in the diabetic population in developing world by 2025. The global prevalence of diabetes is projected to increase from 4% in 1995 to 5.4% by 2025, with developing countries expected to have a 170% increase in the number of diabetics (Azeem *et al.*, 2020).

Increased consumption of low-glycemic foods high in resistant starch, non-starch polysaccharides, and oligosaccharides is advised by the FAO-WHO Expert Consultation (Bibiana *et al.*, 2014). According to Aider *et al.*, (2012), sweet potato is reported to have a low glycaemic index (55), which suggests that they are suitable as a diet for diabetics. Bibiana *et al.*, (2014) reported that foods with low glycaemic responses can help with the control of weight, type 2 diabetes, and obesity.

The development of appealing processed products from composite flour produced from indigenous crops will play an important role in raising awareness on the potential of the crops (Bolarinwa *et al.*, (2019). The β -carotene content in OFSP would be very useful in alleviating vitamin A deficiency among children and adults (Baah *et al.*, 2022).

According to Okereke *et al.*, (2021), the prevalence of vitamin A deficiency in African countries is very high. Given that vitamin A deficiency impairs numerous functions and, as a result, can lead to many health consequences such as impaired iron mobilization, growth retardation, blindness, reduced immune response, increased susceptibility to infectious disease, and increased childhood mortality in most developing countries (Liu *et al.*, 2016; Xu *et al.*, 2021). Therefore, OFSP and Bambara groundnut would address the issue of vitamin A deficiency, ensure food security, improve health, address the issue of malnutrition, increase farming and economic activity on the African continent, and create wealth.

2.2 Bambara groundnut

Bambara groundnut (*Vigna subterraneae*) is a West African groundnut that has spread throughout sub-Saharan Africa's semi-arid zone (Linnenann and Azam–Ali, 1993; Awolu and Oseyemi, 2016). It belongs to the *Fabaceae* family (Yemisi *et al.*, 2011). The Bambara groundnut is native to Nigeria's Jos Plateau and Yola, as well as Cameroon's Garoua (Ferial *et al.*, 2011; Majola *et al.*, 2021).

Jugo beans (South Africa), *Izindlubu* (Zulu, South Africa), *Indlubu* (Xhosa, South Africa), *Ntoyo* (Cibemba, Republic of Zambia), *Nyimo* (Shona, Zimbabwe), *Okpa* (Ibo, Nigeria), *Epa-Roro* (Yoruba, Nigeria) and *Kwaruru* (Hausa, Nigeria) are some of the names for Bambara groundnut (Bamshaiye *et al.*, 2011). Mostly, it is planted as a source of sustainable crop by poor women farmers on soils that are unsuitable for growing other crops (Mkandawire, 2017). The seeds can exhibit a variety of colours (Figure 1).

Bonny *et al.*, (2019) note that Bambara groundnut is Africa's third-largest legume and functions as a low-cost source of protein. However, it is underutilized due to a lack of awareness about its composition as well as possible applications. Moreover, the long cooking time makes it unsuitable for preparing regional dishes.

Bambara groundnut has the same advantages as pearl millet in terms of yielding on low-fertility soils with limited rainfall; yet, it is highly nutritious in comparison with other legumes and people consider it to be their favourite food crop (Mayes *et al.*, 2019). Regardless of its significant nourishment for children, the crop has not been extensively studied; most knowledge and data are kept by farmers in unpublished sources. The international interest in Bambara groundnut is growing since researchers have started to understand the role and importance of this crop in livelihood food security (Filli *et al.*, 2013).

Legumes such as Bambara groundnut, chickpea and soybean can be added to the pasta, pastry products and bakery products (Sanchez *et al.*, 2004; Mubaiwa *et al.*, 2017). Because of its high nutritive content, Bambara groundnut can alter the nutritional composition of meals (Unigwe *et al.*, 2018; Majola *et al.*, 2021). Thus, Bambara groundnut could be used to impart a balanced amino acid profile to cereal grains.



Figure 1: Different coloured Bambara groundnuts. Source: (Maphosa *et al.*, 2022).

2.2.1 Proximate composition and physicochemical properties of Bambara groundnut

Stephens (2013) states that the important amino acid methionine is present in greater abundance in Bambara groundnut protein than in other grain legumes, whereas the oil content is less than half that of legumes like peanuts. The crude protein of Bambara groundnut ranges from 18.68 g/100g to 19.55 g/100g, which is greater than what has been attained from 100% wheat flour (Awolu and Oseyemi, 2016). Okonkwo and Mary (2010) obtained similar results. The amount of protein obtained by Chikwendu, (2008) and Yusuf *et al.*, (2008) ranged between 17.40% and 22.36%.

The nut has an appreciable amount of crude fibre ranging from 1.18 g/100g to 3.71 g/100g. For example, Abu-Salem and Abou-Arab (2011) obtained 3.50% of crude fibre and similar results were obtained by Chikwendu (2008) ranging from 3.30% to 6.10%. Awolu and Oseyemi (2016) obtained the amount of carbohydrate ranging from 68.04 g/100g to 72.89 g/100g which was higher compared to the 100% for wheat flour. The ash content increased as the Bambara groundnut value increased, ranging from 0.53 g/100g to 2.48 g/100g (Oseyemi, 2016).

Okonkwo and Mary (2010) found a low moisture value of the flour of 7.5% which is similar to that one obtained by Chikwendu (2008) and Yusuf *et al.*, (2008). Awolu and Oseyemi, (2016),

reported a moisture content of between 1.32 g/100g and 1.71 g/100 g. The bulk density of the flour obtained by Abu-Salem and Abou-Arab (2011) and Awolu and Oseyemi (2016) which ranged from 0.708 g/cm³ to 0.762 g/cm³ was higher than the one for wheat flour. The high bulk density value improves dispensability while also reducing pasta thickness (Awolu and Oseyemi, 2016).

A high amount of swelling index was reported for Bambara groundnut flour ranging from 4.5% to 8.5% respectively. High starch content results in a high swelling index, which improves the quality of flour. The water absorption index of granules when heated is reflected by swelling power (Awolu and Oseyemi, 2016). The water absorption increases with the increasing protein.

Kinsella (1976) and Awolu and Oseyemi (2016) obtained increase in the water absorption which ranged from 7.15 g/g to 8.05 g/g and the oil absorption ranged from 7.25 g/g to 7.84 g/g. This helps in the preservation of flavour and enhances the palatability of bakery and pasta products (Adebowale and Lawal, 2004). Abu-Salem and Abou-Arab (2011) indicates that the nut contains fair amount of iron (7.6 mg/100g), phosphorus (380 mg/100g), and calcium (73 mg/100g). The results for micro and macro nutrients of Bambara groundnuts obtained by Hillocks *et al.*, (2012) are represented in Table 1.

Table 1: Nutritional composition of Bambara groundnut

Component	Value (mg)
Iron	5.9 – 7.1
Potassium	124 – 129
Phosphorus	296 – 320
Sodium	3.7 – 4.8
Calcium	7.8 – 13.5

Source: (Hillocks *et al.*, 2012; Adegbola and Bamishaiye, 2011; Murevanhema and Jideani, 2013)

2.2.2 Nutritional and health benefits of Bambara groundnut

Bambara groundnut contains 63% carbohydrate, 19% protein and 6.5% fat (Linnemann, 1987; Mayes *et al.*, 2019). Similar results were obtained by Akanniet *et al.*, (2018), who reported the Bambara groundnut contains carbohydrates of 54.5% to 69.3%, protein of 17% to 24.6% and fat content of 5.3% to 7.8%. Kaptso *et al.*, 2013 obtained that nutritionally, Bambara groundnut consists 19.7 % protein, 53.1 % carbohydrates, 6.1 % fat, 6.1 % fibre, 3.4 % ash, 0.098 % calcium and 0.007 % iron. The gross energy value of Bambara groundnut is greater than that of other common legumes such as cowpea, lentil and pigeonpea (Mubaiwa *et al.*, 2018). Content of

Bambara groundnut is comparable or superior to that of other legumes (cow pea and pigeonpea), making it a good complement for cereal-based diets (Kaptso *et al.*, 2013).

Qaku *et al.*, (2020) indicates that Bambara groundnuts have proteins of great quality because they contain more lysine and methionine than other legumes. Unigwa *et al.*, (2017) adds that the fat content of Bambara groundnuts is less than that of legumes like peanuts, with calories ranging from 36 to 414 Kcal/100 g, making it a good complement to cereals in the diet.

According to Jideani (2016), Bambara groundnut is very nutritious and its seed contains about 49%–63.5% carbohydrate, 15%–25% protein, 4.5%–7.4% fat, 5.2%–6.4% fiber, 3.2%–4.4% ash, and 2% mineral. It is a good source of fiber, calcium, iron, and potassium and unusually high in methionine, an essential sulphur-containing amino acid. In terms of lysine, methionine, and cysteine, the essential amino acid content of Bambara groundnut is comparable to that of soybeans (Adedayo *et al.*, 2021).

Noorfarahzilah *et al.*, (2014) argues that because of its high lysine and essential amino acid content, Bambara groundnut can be complementary to other major cereal such as wheat which contains lower amino acids such as lysine. Bambara groundnuts are almost round in shape, with a hard shiny coat in a diversity of colours (Figure 1) including white, cream, and red, brown, black and speckled (Maphosa *et al.*, 2022). The red-coloured Bambara groundnut seed has nearly double the amount of iron compared to the cream-coloured variety, making it important where there is iron deficiency (De Kock *et al.*, 2004; Oludare *et al.*, 2017).

Several medicinal benefits have been reported in addition to its nutritional uses. The Luo tribe of Kenya cures diarrhea using water made from boiling Bambara groundnuts (Adegbola and Bamishaiye, 2011). Abscesses and wounds that are infected can be cured by the leaves, while epilepsy can be treated by the sap of the leaves. Roots are used as aphrodisiac in Senegal while the powder of the seeds is used as cataract treatment (Moreno-Valdespino *et al.*, 2020).

The leaves are used by the Igbos of Nigeria to treat sexual problems (Hillocks *et al.*, 2012). In Botswana, black Bambara groundnuts have a history of being used to treat impotence. In South Africa, uncooked seeds are eaten and swallowed to help pregnant women with nausea and vomiting (Adegbola and Bamishaiye, 2011; Jideani and Diedericks, 2014).

2.2.3 Utilization of Bambara groundnut

One of the limits to the utilization of Bambara groundnut is the lack of processing techniques and this has been linked to difficulty of softening during cooking. The Bambara groundnut may

require longer cooking time to soften, or even does not become tender enough to be acceptable (Mubaiwa *et al.*, 2017). Cooking the dried seed takes a long time, work, and fuel and this is a barrier to its greater use. For example, fresh beans may take 45-60 minutes to boil, while dry beans may take 3-4 hours. It is possible for Bambara groundnut to be used widely if commercially viable quick processing technologies are developed so that the products can be acceptable by the consumer and nutritionists (Filli *et al.*, 2013).

Bambara groundnut is a common 'back garden' and 'snack' crop in sub-Saharan Africa. Nigeria, like other West African countries, has a variety of traditional recipes. In Nigeria's Ibo States, the groundnuts are eaten as a snack after being roasted, or they can be ground into flour and used to produce bean balls ('akara') after frying the mixture in vegetable oil (Mkandawire, 2017; Redjeki *et al.*, 2020).

In several West African countries, fresh Bambara groundnuts are steamed with salt and pepper and eaten as a snack. The nut is ground into flour to make it more palatable. The flour can be used for making a stiff porridge (Alozie *et al.*, 2009; Ibrahim *et al.*, 2018). Roasted seeds can be boiled, crushed and eaten as a relish. The nuts are consumed fresh in Zimbabwe, as well as dried and saved for later use.

Fresh Bambara groundnuts can be roasted and consumed as a snack as well. This legume is widely boiled and eaten as a snack in South Africa (Mbata *et al.*, 2006; Cook, 2017). Bambara groundnut can be combined with some vegetables to make a relish. The seeds are ground into flour to produce flat cakes and biscuits, or they can be combined with cereals to make porridge. The seeds are occasionally boiled and eaten with plantains in some other East African and West African countries (Hillocks *et al.*, 2012).

2.2.4 Processing of Bambara groundnut flour

During the processing of Bambara groundnut into flour (Figure 2), the product is screened to eliminate the defective ones. Wholesome seeds are cleaned, rinsed, and steeped in distilled water for 12 hours. After that, the seeds are dried inside an oven at 45°C for 24 hours, manually de-hulled, and thereafter milled into flour (Kaptso *et al.*, 2015).



Figure 2: Bambara groundnut flour: Source: Author's concept

2.3 Orange fleshed sweet potato

Sweet potato (*Ipomoea batatas* L. LAM) is a dicot plant of which the cordate or lobed leaves vary greatly among cultivars (Dereje *et al.*, 2020). Xiong and Kaluwasha (2022) states that it is a tuberous-rooted herbaceous perennial (Figure 3), although the crop is grown as an annual and is widely grown in tropical and subtropical regions of the world. It belongs to the *Convolvulaceae* family that includes the morning glory and has over 1000 species and is native to Central America (Woolfe, 1992; Bovell-Benjamin, 2003).



Figure 3: Orange-fleshed sweet potato: Source (Ginting and Yulifianti, 2015)

Sweet potato is the world's seventh intensively grown crop, with over 100 countries producing it (Bovell-Benjamin, 2003; Olubunmi *et al.*, 2017). The provinces of Limpopo, Mpumalanga, Kwazulu-Natal, and the Western Cape are the main sweet potato producing areas in South Africa (DAFF, 2019; Lubinga *et al.*, 2018). Sweet potatoes are usually not cultivated from seeds. Instead, they are produced from cuttings, which is a simple method that works well in subsistence agriculture. There is large variation in anthocyanin content and this contributes to variations in leaf and stem colour. The plant exhibit a vining growth habit which varies among cultivars from erect to spreading (Xiong and Kaluwasha, 2022).

Sweet potato flowers are white or purple, while the leaves are green or purple. Flesh can be white, cream, yellow, orange, or purple (Soison *et al.*, 2015), with orange, white, and cream being the well-known and consumed (Sandhill Preservation Center, 2010). Both tubers and leaves are

consumed (Mohamed *et al.*, 2019). The crop is adapted to low input with a wide geographic distribution and adaptation to marginal conditions, a relative short production cycle, containing a wide range of nutrients, and sensory variation in flesh colours, taste, and texture (Farley and Costanza, 2010). The Agricultural Research Council-Vegetables, Industrial and Medicinal Plants in South Africa developed well-adapted OFSP varieties (Laurie *et al.*, 2015, 2017). Bophelo, a popular informal market variety, is one among them. The imported variety Beauregard dominates the commercial market.

2.3.1 Nutritional and health benefits of orange fleshed sweet potato

OFSP (Table 2), consists of starch, crude fibre, protein, ash, and fat ranges from 42.4-77.3, 1.9-6.4, 1.3-9.5, 1.1-4.9, and 0.2-3.0 g/100 g respectively (Wang *et al.*, 2016). Similar results were obtained by Anchundia *et al.*, (2019) who reported that OFSP consist of carbohydrates (sugars + starch) and protein, crude fibre, fat, and ash in higher amount. The essential minerals and vitamins carotene, lutein, vitamin B1, B2, B6, pantothenic acid, niacin and biotin ascorbate are also high in OFSP (Alam, 2021; Sanchez *et al.*, 2020).

Table 2: Nutritional composition of OFSP

Component	Value g/100g
Total carbohydrates	83.1-87.0
Digestible starch	42.3-60.0
Sucrose	4.7-16.5
Protein	4.3-6.2
Resistant starch	0.6-3.8
Ash	3.3-4.5
Crude fiber	1.9-3.3
Fructose	0.9-6.6
Glucose	1.0-6.5
Fat	1.3-2.2

Range (min–max) content (g·100 g⁻¹, dry weight basis). Source: Escobar-Puentes *et al.*, (2022)

In comparison to other sweet potato types, OFSP plays an essential part in human diet, nutrition, and phytochemical qualities such as phenolic compounds and carotenoids (Low and Thiele, 2020). It is a carbohydrate and dietary fibre source. Carotenoids found in orange-fleshed sweet potatoes have been associated with the improvement of the immune function and a lower

risk of degenerative diseases like heart disease (Tomlins *et al.*, 2007; Escobar-Puentes *et al.*, 2022).

Carotenoids have also been linked to the prevention of vitamin A deficiency which is among world's three Most prevalent deficiencies, and preschool children in several parts of Africa are considered deficient (Roetter and Van Keulen, 2007; World Health Organization [WHO], 2009; FAO, 2004; Okereke *et al.*, 2021). It can cause stunted growth and development, as well as sluggish academic progress, loss of vision and even total blindness, illness vulnerability, and, in severe cases, mortality.

Sweet potatoes with orange flesh are high in energy and nutrients that can aid those who are deficient in Vitamin A (Burri, 2011; Xu *et al.*, 2021). It is reported that one medium sized orange fleshed sweet potato can provide about twice the β -carotene needed for the recommended daily requirement of vitamin A. Giving vitamin A to patients who are deficient in the vitamin seems to lower the intensity of infections like influenza and diarrhea, as well as baby and maternal mortality, by roughly 30% (Black *et al.*, 2008; Baah *et al.*, 2022).

The OFSP also has a significant quantity of soluble fibre, which aids in cholesterol reduction, as well as antioxidant components that can help prevent coronary heart disease, colon cancer, diabetes, heart disease, and digestive problems (Hagenimana *et al.*, 2001; Fetuga *et al.*, 2014). Liljeberg and Björck (2000) and Adeoye *et al.*, (2021) also indicate that OFSP has a low glycemic index (55).

Low-glycemic-index foods are beneficial for treating obesity and type 2 diabetes (Gelencsér *et al.*, 2008; Fanta and Neela, 2019). OFSP contain phenolic chemicals reduce atherosclerotic cardiovascular and heart disease (Morton, 2001). Vitamins C, E, B, calcium and iron, are abundant in sweet potatoes (Vimala *et al.*, 2011; Mwanga *et al.*, 2021).

2.3.2 Utilization of orange fleshed sweet potato

Due to its high starch content, OFSP have been utilized as an important source of carbohydrates and energy for both humans and livestock (Kim *et al.*, 2018). It is utilized in industrial processing, as feed for livestock, and for human consumption (Low *et al.*, 2010). According to Truong *et al.*, (2018), an alternative home processing methods for OFSP, include freezing (cubes, chunks, strips), canning (juices, purees, jams, jellies), thermal and non-thermal dehydration (flours, flakes), frying and baking (chips, strips), and microbial fermentation (beverages, pickles, curd, yogurt).

OFSPs are used in items such as beef patties and noodles (Saleh and Ahmed, 1998; Olumbunmi *et al.*, 2017). Baking items and ready-to-eat sweet potato breakfast cereals contain sweet potato flour (Dansby and Bovell-Benjamin, 2003; Bechoff, 2009; Ndangui *et al.*, 2014). OFSP was used to make a variety of products in African countries participating in the Vitamin A for Africa Initiative (Bach *et al.*, 2021).

In Uganda, OFSP is used to make dry chips, flour, juice, and baby products (Tumwegamire *et al.*, 2007; Olubunmi *et al.*, 2017). Chapatti, crackers, onion bits, crisps, and buns were created in Kenya (Hagenimana and Owori, 2014). Sweet potato pickles and cubes products are popular in Asian nations because of their high β -carotene content. In Asia, OFSP roots have also been used in other food processing methods such starch extraction and stock feeds as root meal, particularly in the raising of pigs (Prakash *et al.*, 2017). In South Africa, the roots are commonly eaten after being cooked, baked, or turned into fried chips (Limroongreungrat and Huang, 2007; Low *et al.*, 2020). OFSP leaves are also commonly eaten in some parts of Tanzania (Kapinga *et al.*, 2007).

The roots of OFSP have been utilized as a flour and in the grated and mashed (commonly known as puree) forms locally at domestic level and in industrial production of bakery product in many countries (Abidin *et al.*, 2015; Escobar-Puentes *et al.*, 2022). Some of the bakery products in which OFSP flour is incorporated as an ingredient are cakes, bread, muffins and buns (Behera *et al.*, 2022). To increase the provitamin A content of the bread, OFSP puree is added as a functional ingredient (Behera *et al.*, 2022). The substitution of wheat flour with OFSP puree in bread baking has been done at varied levels in different studies (Owade *et al.*, 2018). Because of its naturally present of dietary fibre content, OFSP has been recognized as a highly nutritious and useful food for the prevention of chronic diseases (Prakash *et al.*, 2017).

2.3.3 Processing of orange fleshed sweet potato flour

During the processing of OFSP into flour (Figure 4), the sweet potato is washed, peeled, trimmed and sliced. The sliced sweet potato is blanched for 5 minutes, then dried and finally ground to produce flour and sieved (Taneya *et al.*, 2014; Chikpah *et al.*, 2020). OFSP can be dried using hot air convection oven drying. Excessively hot air in an oven can completely dry the solid surface, causing its pores to contract and close, resulting in crust formation or "case hardening", which is usually undesirable (Onwude *et al.*, 2019).



Figure 4: Orange fleshed sweet potato flour: Source: Author's concept

Thus, Moyo *et al.*, (2014) recommends that throughout the drying process, the right temperature and duration (105°C for 24 hours) should be used. Tadesse (2022) observes that oven drying provides a homogeneous, sanitary, and nicely coloured dried product. Similarly, Ogunlakin *et al.*, (2012) found that oven drying has a greater impact on the nutritional and functional properties of cocoyam flour than direct sun drying. However, regardless of the advantages of an oven drier, it is an energy-intensive process.

2.3.4 Proximate composition of orange fleshed sweet potato flour

a) Proteins

Protein is necessary for human growth and can also be used in dietary compositions to serve functional tasks. Despite its reputation as a high-energy, low-protein diet, OFSP's protein level is acceptable in both fresh and floured forms (Hal, 2000; International Life Science Institute ILSI, 2008; Chikpah *et al.*, 2020).

Alam *et al.*, (2016) indicates that there is a significant difference of OFSP protein ranging from 1.9% to 5.83%. Olubunmi *et al.*, (2017), found that protein in OFSP flour range from 3.14 % to 6.57%. Similarly, Omodamiro *et al.*, (2013) and Truong *et al.*, (2019) obtained a high protein content ranging from 3.9% to 6.93%.

b) Fats

Olubunmi *et al.*, (2017) states that the fat content of OFSP varies greatly depending on the treatment and drying procedures used. Alam *et al.*, (2016), reports that the fat content of most OFSP types is low (0.17%±0.10%). Similar results were obtained by Vital *et al.*, (2023). Olubunmi *et al.*, (2017), surmises that the low value of fat content in sweet potatoes is caused by fat oxidation during the drying process of the samples.

c) Fibre

Vital *et al.*, (2023) indicates that the intake of dietary fibre can improve serum lipid levels, assist in glycemic control, reducing blood pressure levels and it is important for good intestinal functioning, including irritable bowel syndrome, cancer, and diabetes. Eating fibre softens stools and lowers blood cholesterol levels in the body (Olubunmi *et al.*, 2017; Adigwe *et al.*, 2023). Omodamiro *et al.*, (2013), notes that the fibre level of OFSP ranges from 0.67g/100g to 2.00g/100g.

d) Carbohydrates

Since OFSP contain great amount of carbohydrates, its flour is an excellent energy source and nutrition (Bibiana *et al.*, 2014; de Souza *et al.*, 2021). It also aids fat metabolism, acts as a mild natural laxative, and stores proteins as a source of energy (Gordon, 2000; Giri and Sakhele, 2019). Olubunmi *et al.*, (2017) established that the proportion of carbohydrates in OFSP flour ranged from 56.31% to 65.45%. However, Omodamiro *et al.*, (2013) found that sweet potato total carbohydrates ranged from 20.28% to 33% and differed with varieties ($P < 0.05$).

e) Ash content

The ash content of a food product reflects the mineral content of the product. Oloniyo *et al.*, (2021) indicates that the ash content of OFSP flour ranges from 2.70% to 3.00%. Omodamiro *et al.*, (2013) found that the amount of ash in the samples ranged from 0.50% to 1.52%. The decrease in proximate composition of OFSP flour is attributable to different techniques of flour processing and pretreatment (Hal, 2000; Giri and Sakhale, 2019). Osundahunsi *et al.*, (2003) notes that pretreatment comprising leaching, such as blanching and grilling, reduces the protein, fat, crude fibre, carbohydrates, and ash content of OFSP flour sample.

2.3.5 Functional and physicochemical properties of orange fleshed sweet potato flour

a) Moisture content

Moisture analysis determines the total amount of free water and bounded water in food material. Food processing operations require knowledge of the moisture content which plays a role in the quality of food. Moisture content determination in a food product is critical for legal and labeling requirements, as well as microbial stability and processing processes that require moisture content knowledge during mixing, drying, packaging, and storage (Mulvaney and Cunniff, 2009). The amount of moisture in food affects its texture, taste, appearance, and stability;

also, the propensity of microorganisms to grow in foods is influenced by its moisture level (Isengard, 2001; Dereje *et al.*, 2020).

To measure moisture content in food, either indirect or direct methods are used. Indirect method includes gravimetric, azeotropic distillation, Fischer titration and extraction methods which are highly accurate, whereas the direct method includes electrical-electronic, sonic, ultrasonic and spectroscopic methods which offer automatic moisture content control during processing (James *et al.*, 2010; Ma *et al.*, 2021). Moisture analyses are rapid and the equipment available in the market. Traditionally, using an oven is a well-established, reliable, simple to operate and accurate method for moisture analysis. Several researchers have analyzed the moisture content of sweet potato using different techniques.

Korese *et al.*, (2021) investigated the moisture content of two types of sweet potatoes, orange-fleshed and yellow-fleshed sweet potatoes, and found that fresh sweet potatoes contain moisture value ranging from 56.30% to 84.90%. However, Ingabire and Vasanthakalam (2011) found that the moisture values of sweet potato varieties ranged from 62.58% to 64.34%. This suggests that the contrasts in moisture content between sweet potato varieties are caused by genetic differences as well as agro-cultural practices. Sweet potatoes, like most roots and tubers, have a high moisture content, which affects how long they last (Antonio *et al.*, 2011).

Sanni *et al.*, (2009) says that the maximum moisture value of sweet potato flour should be around 13% because this allows the flour to be stored for longer periods of time without spoiling due to microorganisms. Sanni *et al.*, (2009) also observed that moisture content were not statistically different within the different drying methods which ranged from 6.27% to 8.94%. However, Van Han (2000) found that flour moisture value is directly related to the process of drying, drying time and period, also storage conditions, with moisture content ranging from 4.4% to 13.2%. Solar drying can achieve moisture levels of roughly 8%, whereas artificial dryers can achieve moisture levels of as low as 2-3% (Van Han, 2000).

b) Colour

Colour analysis is critical for determining the impacts of raw components on the finished product, its shelf life or changes due to processing, ensuring suppliers are providing consistent coloured material, and determining if the final product meets internal quality standards (Antonio *et al.*, 2011). The colour of sweet potato flour may be determined by Minolta chromameter in which the colour of the flour is depicted by the L*, a*, b*, c* and h⁰ notation using the method described by Dery (2012). In this method, the instrument is first calibrated by a white tile as the

standard (control) followed by tightly packing sweet potato flour in a clean petri dish and covered with another petri dish.

The flour is then placed on the white tile and the Minolta chromameter is placed over the dish. The intensity of the colour is measured using L^* , a^* , b^* notation when light from the Minolta chromameter is shone on the sample. L^* values are zero for black and 100 for white, with a^* (red-green) representing the degree of redness (0 to 60) or greenness (0 to -60) and b^* (yellow blue) representing the degree of yellowness (0 to 60) or blueness (0 to -60) respectively (Perez-Magarino and Gonzalez-Sanjose, 2003).

Chroma (c^*) notation indicates the quality of a colour's purity, intensity or saturation and it is determined by calculating the a^* value and b^* where $c^* = \sqrt{a^{*2} + b^{*2}}$ indicating that the high value of a^* and b^* results in high c^* . Hue angle (h°) is the common distinction between colours positioned around a colour wheel and it is also determined by a^* and b^* value where $h^\circ = b^*/a^*$ indicating that b^* value increases with the decrease in h° , and a^* value increases with the increase in h° (Kim, 2006).

The flesh of sweet potatoes can be white, yellow, orange, or purple and their thin skin might be white, yellow, orange, red, or purple in colour. Schertz (2008) observes that the diverse colours in sweet potatoes are due to the type, isolation, and chemical structure of the many chloroplast pigments. Furthermore, Mais and Brennan (2008) note that the appearance of sweet potato flour, particularly its colour, is an essential quality aspect that influences the attractiveness of the flour and the food product generated from it. Dery (2012) states that the presence of polyphenolic compounds, ascorbic acid, carotenes, and other chemical substances in flour affects its quality.

Flour can be whitish or cream-coloured, or varied colours of yellow, orange, or pale purple, depending on the type and processing procedures. For most flours and starches, low a^* and high Lightness (L^*) are recommended. Sweet potato flour's colour is determined by several complicated biochemical processes, including natural pigments, which impact the flour's redness and yellowness (Dereje *et al.*, 2020).

2.4 Background on pasta

Pasta is an Italian word that means "paste" and refers to a variety of flour and water-based goods of various forms and sizes. It is a collective term that refers to grain products such as spaghetti, noodles, macaroni and vermicelli (Balasubramanian *et al.*, 2006; Gull *et al.*, 2015). Pasta products are traditionally made with durum wheat semolina, water, and eggs. Beside the

basic ingredients, pasta products have limitless shapes and names and yearly, more are added (Balasubramanian *et al.*, 2006; da Silva *et al.*, 2016).

Pasta can be classified into three types: dried semolina pasta, fresh egg pasta, and fresh eggless pasta. At home or in restaurants, fresh pasta is frequently prepared (Sadehi and Bhagya, 2008; Massaro and Galiano, 2020). It comes in a variety of shapes that can be used for decorating as well as serving as a carrier for various sauces. There are stuffed pastas like ravioli and tortellini which are filled with ground meat or cheese (Serventi and Sabban, 2002).

Fuad and Prabhasankar (2010) argue that pasta is one of the oldest forms of nutrition and a very adaptable food from both a nutritional and a gastronomic standpoint. Savita *et al.*, (2013) observes that it is necessary to increase the quality of pasta by adding other components because as a wheat-based staple food it comes second to bread in terms of global consumption.

Pasta is a carbohydrate source (74% to 77% on a dry basis), and its popularity is growing because of its nutritional benefits such as its low glycaemic index (GI) (Monge *et al.*, 1998; Olubunmi *et al.*, 2017). Pasta also has 11% to 15% protein. However, it is lacking in lysine and threonine which are the first and second limiting amino acids found in most cereals (Abdel-Aal and Hucl 2002; Gao *et al.*, 2018). This opens the possibility of using non-traditional raw ingredients to increase the nutrients of pasta (Del Nobile *et al.*, 2008).

Pasta has undergone a remarkable transformation in recent years as manufacturers and culinary enthusiasts experiment with non-wheat alternatives to cater to various dietary preferences and requirements. Recently pasta has been produced from items other than wheat, such as legume-based pasta, particularly chickpea, lentil, and pea-based varieties, which has gained popularity due to its high protein content and gluten-free nature (Smith, 2019); Rice and quinoa, being naturally gluten-free grains; Vegetable-Infused Pasta which offers both unique flavours and nutritional benefits; and alternative flour pasta such as almond, coconut, and tapioca, which have gained traction in gluten-free pasta production (Garcia and Torres, 2020; Torres, 2021 and Patel and Singh, 2022). The manufacturing of pasta from non-wheat ingredients has seen significant progress, driven by research and innovation in ingredient selection, processing techniques, and equipment advancements. These developments offer consumers a broader range of pasta options, catering to various dietary needs while maintaining the delicious and comforting qualities that pasta enthusiasts adore (Li, X *et al.*, 2023).

2.4.1 Nutritional benefits of pasta

Pasta is a low-calorie, low-fat, cholesterol-free, and sodium-free food. Thiamine, iron, riboflavin, and niacin are all found in abundance in pasta (Savita *et al.*, 2013). It also consists of significant proportion of complex carbohydrates, proteins, B-vitamins, and amino acids, making it a great source of energy for both the body and the brain (Fuad and Prabhasankar, 2010; Savita *et al.*, 2013).

2.4.2 Processing of pasta

Pasta processing (Figure 5) is the process of combining semolina wheat flour or composite flour with water, extruding the dough into a certain form, and then cooked by boiling or baking (Olubunmi *et al.*, 2017). Pastas are divided into two broad categories which are dried and fresh. Most dried pasta is produced commercially via an extrusion process, although it can be produced at home. Fresh pasta is traditionally produced by hand, sometimes with the aid of simple machines (Dey *et al.*, 2021). The essential ingredients in pasta are 100% durum flour and water; however, non-durum flours can be used to replace a small amount of durum flour (Safriet, 1995; Hal, 2000; Fuad and Prabhasankar, 2010; Savita *et al.*, 2013).

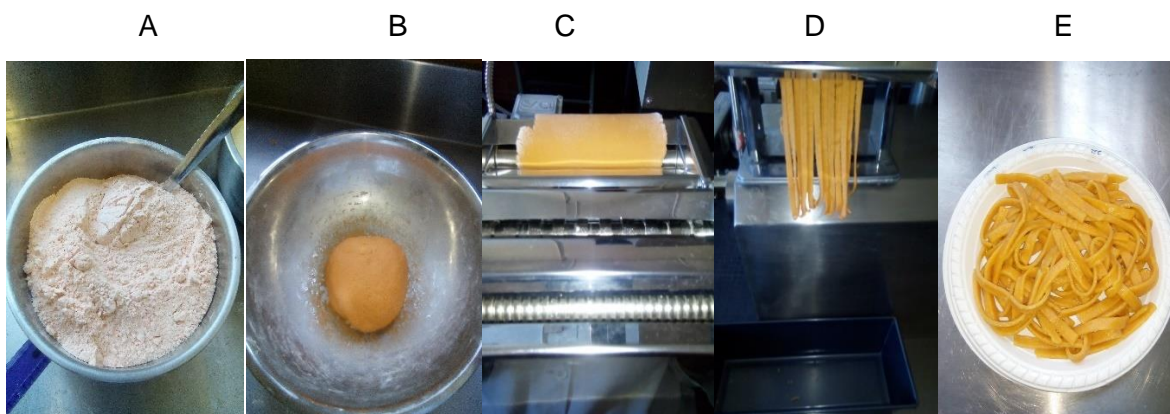


Figure 5: Processing of dry pasta: Source: Author's concept (A: Ingredients, B: Dough, C: Rolling, D: Cutting and E: Final product)

Process control has an impact on the quality of pasta. Safriet (1995) and Park and Balik (2002) state that pasta products have been manufactured for centuries, but due to the lack of production equipment and high-quality ingredients, they have only been available as a retail product since the twentieth century. Prior to the industrial revolution, most pasta products were made by hand in small businesses. Pasta is currently made with continuous, high-capacity extruders that employ the auger extrusion principle which combines kneading and extrusion into a single operation.

The technique of forcing a material out of a chamber or cylinder through a tiny opening utilizing pressure differentials between the interior and exterior of the chamber is known as the extrusion process. With the kneading and extrusion of the dough, the automatic press begins the process of combining flour, water, and any other ingredients components required for the specific product. This is a continuous process with a shaping mechanism that determines the shape of the extruded goods. Following extrusion and shaping, the pasta is transported to a dryer for final moisture reduction, ensuring product preservation and distribution stability (Walsh and Gilles, 1977; Safriet, 1995; Marti *et al.*, 2014).

Heat and humidity must be managed during the drying process to dry the pasta without affecting the end product's quality. Olubunmi *et al.*, (2017) observes that there is insufficient research on the use of extrusion in sweet potato processing; thus, there is a need to investigate the potential for using extrusion process to improve the variety of OFSP consumption.

Considering the growing popularity of pasta and the importance of OFSP, and Bambara groundnut nutritional benefits and economic constraints, the current study evaluated the effect of the addition of OFSP and Bambara groundnut on the functional, physicochemical, thermal properties and sensory characteristics of pasta.

2.4.3 Chemical composition of pasta

a) Moisture

Ogawa and Adachi, (2023) states that moisture affects the weight, density, viscosity, refractive index, and electrical conductivity of food products and is a quality factor in food preservation. Thuy *et al.*, 2020 found the moisture content of OFSP pasta to be 14.5%. However, Effiong *et al.*, (2018) found moisture level of OFSP pasta that ranged from 11.53% to 13.24%. Olubunmi *et al.*, (2017) indicates that because of microbiological activities in the products, which induce decomposition, the shelf life of pasta is often determined by its moisture content.

b) Protein

Proteins are large biomolecules or macromolecules that are made up of one or more long chains of amino acids. Ginting and Yulifianti (2015) state that the protein value of OFSP pasta ranges from 11.15% to 18.86%. Effiong *et al.*, (2018) found protein values of OFSP pasta ranging between 11.67 and 13.04. The more protein in the pasta, the more elastic the texture and the lower the hardness.

c) Fats

Fat is one of the three major macronutrients, and it is a significant source of energy for a variety of organisms (Grainger *et al.*, 2020). Mozaffarian *et al.*, (2006) observes that it also serves structural and metabolic roles. Effiong *et al.*, (2018) found significantly lower values of fat content ranging from 0.71% to 8.33%. Cappaet *et al.*, (2022) found different results. The difference in fat value between the two experiments could be due to the components and processing technique used, and the type of flour used to make pasta. Effiong *et al.*, (2018) state that the low-fat content of pasta is helpful to human health because it minimizes the rate of cholesterol formation in the body.

d) Fibre

Effiong *et al.*, (2018) found a 2.13% to 3.38% increase in the value of OFSP pasta. Jalgaonkar and Jha (2016) say this is likely caused by higher fibre content of OFSP. Effiong *et al.*, (2018) indicate that FAO/WHO recommends that fibre level of dietary products ingested by children and adults should not exceed 5%.

e) Carbohydrates

Some cells, such as those in the nervous system and red blood cells use carbohydrates as their primary fuel source to support high physical activity, muscles also rely on a steady supply of carbohydrates (Atuna, 2020). Effiong *et al.*, (2018) observes that there is a significant difference in the values of OFSP pasta ranging from 67.90% to 70.90%.

f) Ash content

The process of mineralization for pre-concentration of trace components prior to chemical analysis such as chromatography or optical analysis such as spectroscopy is known as ash content determination (Sluiter *et al.*, 2008; Fu *et al.*, 2022). Effiong *et al.*, (2018) obtained ash level ranging from 1.35% to 2.11% in OFSP pasta.

g) Colour

Olubunmi *et al.*, (2017) argue that colour is essential because of its impact on acceptability of food products. Since colour has a relationship to product freshness and flavour expectations, it is an essential quality for food acceptance and has a direct impact on consumer impressions. Bianchiet *al.*, (2021) observes that coloured pasta products have become increasingly popular in

recent years because of their favourable influence. Reungmaneevaitoon (2009) found that OFSP pasta is darker (lower L^* value) and has greater chromaticity (higher a^* and b^* value) than white fleshed sweet potato pasta. However, Ozyurt *et al.*, (2015) found an increase of darkness (L^*) and high (b^*) value in the colour of pasta. Similar findings were noted by Fradique *et al.*, (2010); Zourai *et al.*, (2011) and Lemes *et al.*, (2012).

CHAPTER 3: MATERIALS AND METHODS

3.1 Materials

3.1.1 Raw materials

Experiments were conducted to determine how composite flour derived from orange fleshed sweet potato (*Ipomoea batatas* (L.) LAM) and Bambara groundnut (*Vigna subterranean* (L.) Verdc) affects the nutritional, functional, cooking and sensory properties of pasta.

OFSP cultivar Bophelo was produced at the Roodeplaat campus of the Agricultural Research Council-Vegetables, Industrial and Medicinal Plants (ARC-VIMP). Bophelo was released by the ARC-VIMP in 2011 as part of developing varieties with sweet and dry taste for the informal market (Laurie *et al.*, 2017). The variety is promoted as part of a crop-based approach to address vitamin A deficiency. Roots of OFSP were sorted, cleaned and kept at room temperature in the agro-processing facility. The Bambara groundnut seeds (*Vigna subterraneae*) were purchased from the Thohoyandou street market in the Limpopo Province. Snowflake Semolina flour was purchased from Shoprite, Gauteng Province, South Africa. The study was conducted at the plant breeding Agro-processing facility of ARC-VIMP.

3.1.2 Equipment

Petri dishes, crucibles, water bath, incubator, thermometer, test tubes, conical flask, bowls, buckets, knife, vegetable peeling machine, vegetable cutting machine, hot air oven dryer, milling machine, sieve and pasta processing machine were provided by the ARC-VIMP and the Department of Food Science and Technology of the University of Venda.

3.1.3 Chemicals

Phosphate buffer, sodium chloride peptone buffer, DPPH, sodium hydroxide, sulfuric acid, iron sulfate, ascorbate, thiobarbituric acid, potassium sulfate, hydrochloric acid, distilled water, petroleum ether, and potassium hydroxide were provided by the ARC-VIMP in Pretoria. All the chemicals were supplied by Merck Group Company.

3.2 Methods

3.2.1 Preparation of Bambara groundnut flour

The Bambara groundnut flour (Figure 6) was prepared according to the method described by Kaptso, (2015). The nuts were washed, rinsed, and steeped in distilled water for 12 hours. After

that, the soaked nuts were drip-dried for 30 minutes before being placed in an oven dryer, manufactured by Dryers for Africa (model CM-HSKX) set at 60°C for 24 hours. Next, the nutscoats were dehulled by hand and placed into an electric grain grinder mill/hammer mill (model DLF-20) to produce flour. The flour was then passed through sieves of 1.0mm and packaged in bags.

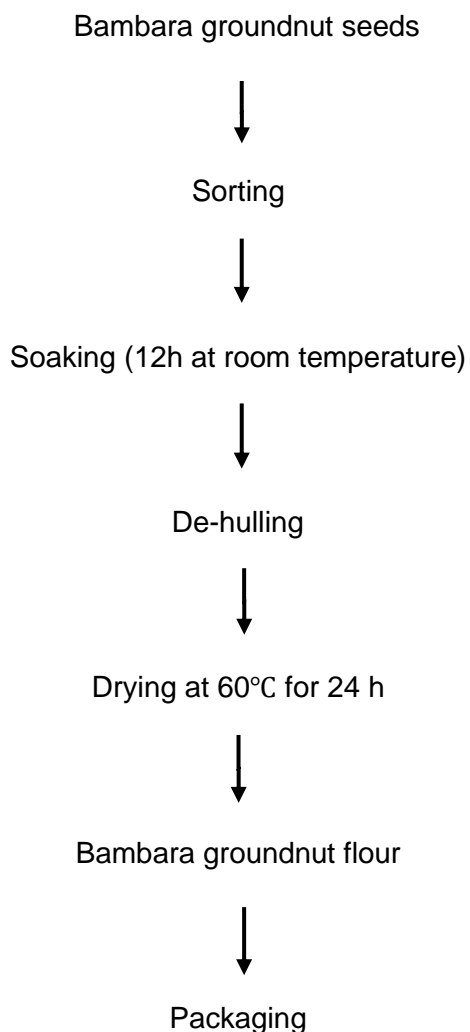


Figure 6: Process flow diagram for preparation of Bambara groundnut flour

Source: (Kaptso *et al.*, 2015).

3.2.2 Preparation of sweet potato flour

The processing of OFSP flour (Figure 7) was carried out according to a method described by Taneya *et al.*, (2014). OFSP were washed using tap water, peeled using the Anvil potato peeling machine, trimmed and sliced into 2mm thickness using a vegetable cutting machine (Anvil, Model HCL-300), which was obtained from the ARC-VIMP agro-processing facility. The sliced sweet potatoes were blanched for 5 minutes, then dried for 8-10 hours in hot air oven dryer, manufactured by Dryers for Africa (model CM-HSKX) at 60-65°C, before being ground to flour using hammer miller (model SF-130) . The flour was then passed through a 1.0mm sieve.

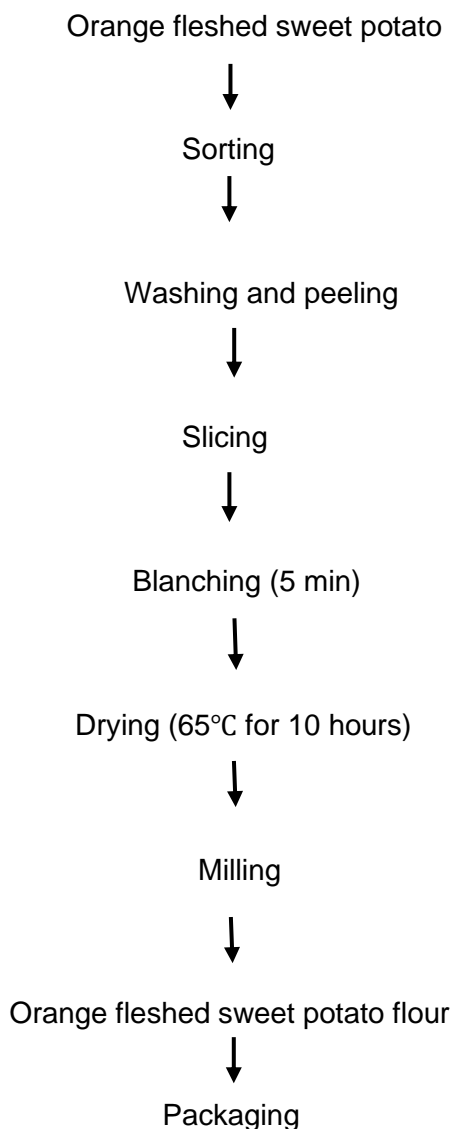


Figure 7: Process flow diagram for the preparation of orange-fleshed sweet potato flour

Source: (Taneya *et al.*, 2014).

3.2.3 Processing of pasta

The ratios used to produce pasta were 90:5:5; 70:15:15 and 50:25:25 for Semolina wheat flour: OFSP flour: Bambara groundnut flour, respectively. The pasta processing flow is depicted in Figure 8. About 0.5g of salt was added to the flour mixtures of each ratio which had been placed in large bowls. For each ratio 473ml of warm water (35°C) were poured into the flour mixture, while mixing quickly with a fork until the pasta dough was adequately wet to make stiff dough. The dough was formed into a ball and kneaded for 10-15 minutes on a lightly floured board until it became stiff, smooth, and elastic. The dough ball was covered with plastic wrap and allowed to rest for 20-30 minutes before being flattened out to a thickness of 5mm and cut into the desired shape using a pasta machine and dried inside drying trays for 3 hours at 75°C using a hot air oven dryer manufactured by Dryers for Africa, model CM-HSKX (Bashir *et al.*, 2012; Obadi *et al.*, 2021).

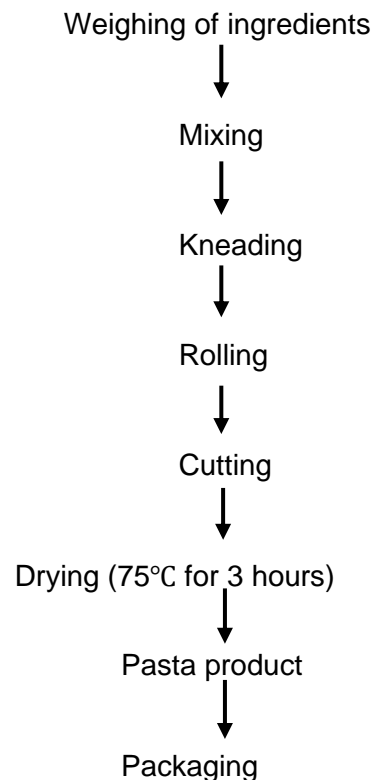


Figure 8: Flow processing diagram of orange-fleshed sweet potato pasta
Source: (Obadi *et al.*, 2021)

3.3 Experimental design

A randomized design was followed with four treatments. Composite pasta was 90:5:5; 70:15:15 and 50:25:25 for semolina, OFSP and Bambara groundnut flour, respectively (Figure 9). Pasta produced from 100% wheat pasta was used as a control. The experiment was carried out in triplicate. Figure 9 represents the process flow for the experimental procedures. Following the preparation of OFSP and Bambara, including drying, the OFSP, Bambara and semolina were prepared into pasta in various ratios. The resultant pasta treatments were subjected to proximate analysis, determination of functional and cooking properties and sensory evaluation.

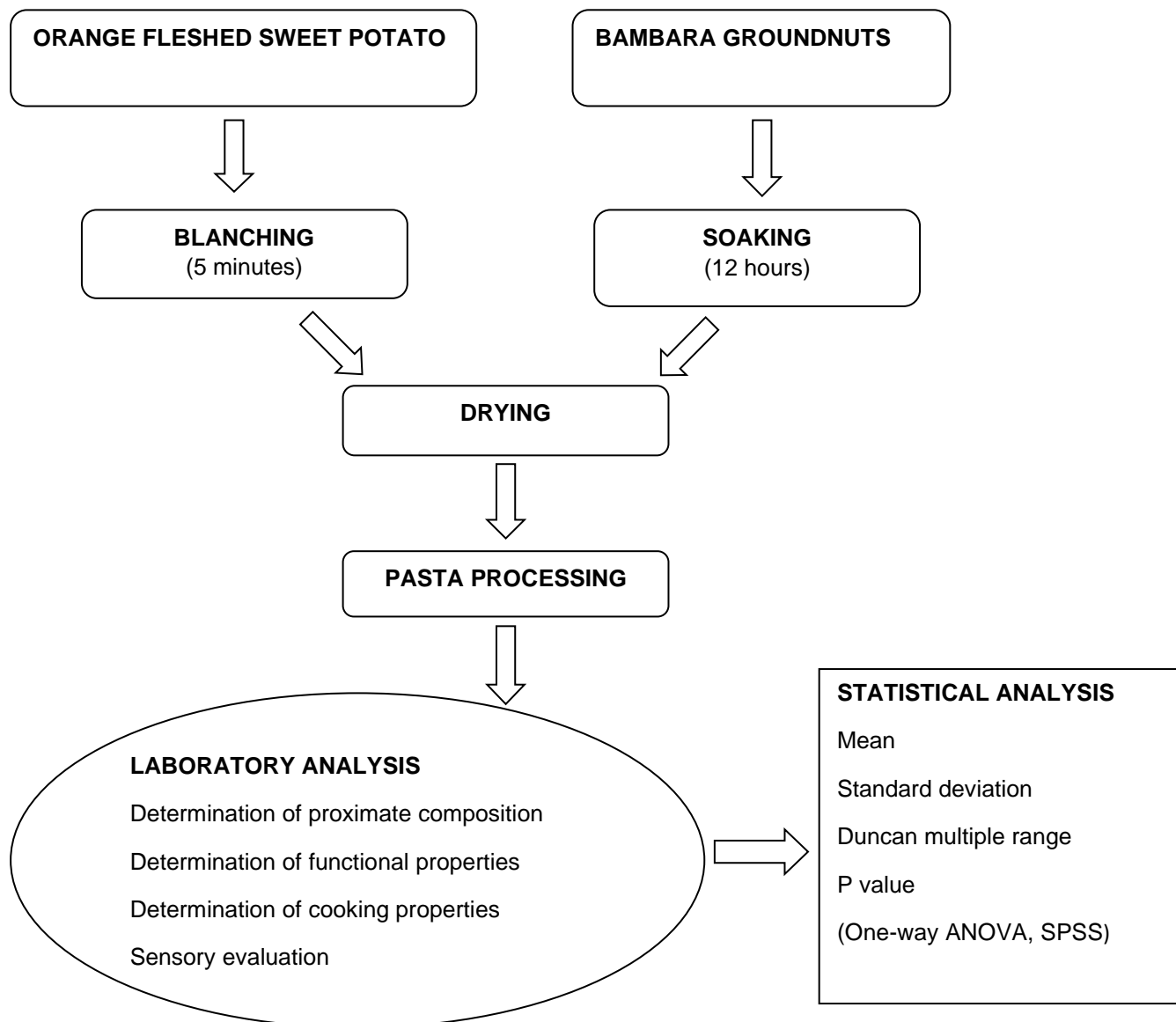


Figure 9: Sample preparation

Source: Author's concept

3.4 Physicochemical properties

3.4.1 Proximate composition

Moisture, total ash, crude protein (N x 6.25), fat, and fibre were measured using the Official Methods of Analysis of the AOAC (2000) International 925.09, 923.03, 979.09, 945.38F, and 962.09, respectively. The following equations were used:

$$\text{Carbohydrates} = 100 - \% \text{ fat} - \% \text{ protein} - \% \text{ moisture} - \% \text{ ash} - \text{ fibre}$$

$$\text{Energy value} = (\% \text{ carbohydrate} \times 4 + \% \text{ fat} \times 9 + \% \text{ protein} \times 4)$$

3.4.2 Vitamin A determination

Vitamin A was determined according to method described by Ayhan and Köksel, 2019; Bolarinwa *et al.*, 2021. Two grams (2g) of each sample was poured into a beaker followed by addition of 10ml chloroform solution. The solution was heated to 100 °C and incubated for 1 hour. The chloroform layer was transferred to another test tube. A saturated solution of antimony trichloride reagent was added to the tube, and blue colouration was observed. The spectrophotometer was adjusted to read the absorbance of the resulting solution at 620nm against a reagent blank. Below is how the outcome was calculated (Bolarinwa *et al.*, 2021).

$$\frac{A_{st} \times C_{td} \times D.F}{A_{td} \times W} = \text{mg}/100 \text{ g of vitamin A}$$

Where:

A_{st} = Absorbance of test

C_{td} = Concentration of standard

D.F = Dilution factor

A_{td} = Absorbance of standard

W = Weight of the sample

3.4.3 Vitamin C determination

Vitamin C was measured using the Mahonmmed *et al.*, (2009) method which involved dissolving 0.05g standard crystalline ascorbic acid in 100ml distilled water to make a 500ppm standard stock solution. Thus, a 10g sample was homogenized in 50ml of acetic acid solution, then transferred to a 100ml volumetric flask and gently stirred until it produced a homogenous dispersion. The solution was then diluted with acetic acid solution to the desired concentration, filtered, and the clean filtrate was collected for vitamin C analysis.

3.4.4 Colour measurements

The Hunter Lab System was used to determine colour (Martinez-Romero *et al.*, 2006). Each sample was weighed at approximately 6g, and the beaker containing the sample was placed in a LabScan XE Spectrophotometer with enlightens D65 as the light source. The L*, a* and b* colour coordinate values were measured. The outcomes were presented as positive L* (lightness), a* (redness) and b* (yellowness) colour space value. Each sample was measured in triplicates and the data was presented in averages.

3.5 Functional properties

3.5.1 Bulk density (BD)

The bulk density was determined according to method by Onwuka (2005). A 10ml graduated cylinder was filled with approximately 2.5g of material and tapped on the laboratory bench until the sample volume did not drop. The bulk density was determined by dividing the weight of flour (g) by the volume of flour (ml). The result was calculated as follows:

$$\text{Bulk density} \left(\frac{g}{ml} \right) = \frac{\text{weight of sample (g)}}{\text{volume of sample after tapping (ml)}}$$

3.5.2 Water absorption capacity (WAC)

In a centrifuge tube, 1g of pulverized sample was suspended in 10ml of distilled water. The contents were shaken and centrifuged for 30 minutes at 3,000 rpm. WAC was computed as the grams of gel obtained per unit gram of sample after the supernatant liquid was discarded and the residual gel was weighed (Anderson *et al.*, 1969; Adebowale *et al.*, 2005). The water absorption capacity was calculated using the formula below:

$$\text{Water absorption index} = \frac{\text{grams of gel}}{\text{unit gram of sample}}$$

3.5.3 Oil absorption capacity (OAC)

In a centrifuge tube, 10ml oil was added to 1g flour to test oil absorption ability. A vertex mixer was used to stir the tube for 2 minutes. It was centrifuged for 30 minutes at 3000 rpm. The amount of free oil was measured and decanted. The formula for oil absorption capacity is ml of oil bound by 1g dried flour (Adeleke and Odedeji, 2010).

3.5.4 Swelling power and solubility

In a clean, dry pre-weighed 10ml centrifuge tube, 1g wheat and composite powder of OFSP and Bambara groundnut was weighed and combined with 10ml distilled water. The centrifuge tube and contents were heated in a water bath at 80°C for 30 minutes while being constantly shaken. The tube was removed from the bath, dried, cooled to ambient temperature, and then centrifuged at 2200 rpm for another 15 minutes. The supernatant was evaporated and the dry residue weighed to measure the solubility. The following formula was used to calculate solubility:

$$\% \text{ Solubility} = \frac{\text{weight of dried sample in supernatant}}{\text{weight of original sample}} \times 100$$

To quantify the swelling power, a swollen sample obtained by decanting the supernatant was weighed and the swelling power was determined as follows (Saroh *et al.*, 2019):

$$\text{Swelling power} = \frac{\text{weight of wet mass sediment}}{\text{weight of dry matter in gel}} \times 100$$

3.6 Pasta Quality Parameters

3.6.1 Cooking Procedure

The pasta was cooked using a method outlined by Bustos *et al.*, (2011). All cooking tests were carried out three times. Pasta (4g) was broken into pieces of 5cm and cooked in boiling distilled water (200ml). Throughout the cooking procedure, the water temperature (100°C) was kept at this level. Each sample's cooking time was calculated.

3.6.2 Cooking Loss

The method described by Tudorica *et al.*, (2002) was used to determine the cooking loss of pasta. Evaporation to constant weight in hot air oven dryer, manufactured by Dryers for Africa (model CM-HSKX) at 105°C was used to gather water from each sample. The residue was weighed and the percentage of the raw pasta sample was reported.

3.6.3 The Optimum Cooking Time

After cross-cutting the pasta, the optimal cooking time was recorded as the moment when the white inner core vanished according to the AACCC (2000) method.

3.6.4 Cooked Pasta Textural Analysis

A texture analyzer (model TAX-500) with a Windows version of the Texture Expert Software package was used to make texture analyses according to the procedures outlined by Bustos *et al.*, (2011).

3.7 Sensory evaluation

On a 9-point hedonic scale (1 = extremely dislike to 9 = extremely like) (see Appendixes), 100 untrained panelists, employees from the Agricultural Research Council (ARC-VIMP) rated the overall acceptability, colour, texture, appearance, taste, mouth feel, and hardness (score card attached on the appendix) of pasta. The panelists had little understanding of the project's goals. The samples were served in a counter-balanced presentation order and were coded with three-digit random numbers. The rating scale was used for all other parameters according to the method described by Larmond (1980). Panelists were provided with a glass of water and were instructed to rinse and swallow water between tasting of the samples.

3.8 Statistical analysis

The experiment was carried out using completely randomised design. All analyses were carried out in triplicate. Results were analysed using statistical software SPSS Version 23.0. (Armonk, NY). The standard deviation was reported along with the mean value of duplicate determinations. Analysis of variance (ANOVA) was performed using statistical software SPSS Version 23.0.(Armonk, NY)and Duncan's Multiple Range Test ($p \leq 0.05$) was used to achieve means separation (Duncan, 1955).

CHAPTER 4: RESULTS AND DISCUSSION

Chapter 4 discusses the results of composite orange fleshed OFSP-Bambara groundnut-semolina pasta and 100% semolina wheat pasta. The important contribution of these two ingredients namely OFSP and Bambara groundnuts is in nutrient fortification, boosting the protein and vitamin A content in pasta are discussed. The study further describes physical properties that are affected when semolina flour is substituted at various levels by the flour from these two ingredients.

The proximate compositions of pasta produced from different ratio of flours are provided in Table 3. The functional properties of various pasta produced using different ratios are presented in Table 4. The vitamins (A and C) results of OFSP-Bambara groundnut pasta are discussed in Table 5, while Table 6 contains the cooking quality of pasta. The results of colour measurements of OFSP-Bambara groundnut pasta are presented in Table 7. Table 8 shows the results of consumer acceptability of OFSP-Bambara groundnut pasta after the sensory evaluation was performed with 100 untrained panelists. The following table (table 3) shows the different samples of pasta, their composition and codes.

Table 3: Summarized table of different samples of pasta

Code	Composition
W100	100% Semolina wheat flour.
W90O5B5	90:5:5 (semolina, OFSP and Bambara groundnut flour).
W70O15B15	70:15:15 (semolina, OFSP and Bambara groundnut flour).
W50O25B25	50:25:25 (semolina, OFSP and Bambara groundnut flour).

4.1 Proximate composition

The nutritional content of OFSP and Bambara groundnut enriched pasta must be assessed to relate this product to healthful qualities. The proximate composition of pasta produced from different ratio of flours is shown in Table 3. According to the test results, there was a significant increase ($P < 0.05$) in moisture content from 8.55% to 11.13%. Sample W50O25B25 (50:25:25

ratio of semolina, OFSP and Bambara groundnut flour) had the highest moisture content, while sample W100 (100% wheat) had the lowest moisture content. Low value of moisture was obtained in all samples (<12), showing a long shelf life when maintained in dry surroundings. This is in accordance with Codex Alimentarius Standards (Arendt, 2018).

Compared to 100% wheat pasta, the addition of OFSP and Bambara groundnut flour to the pasta increases the moisture level of the pasta. This could be because OFSP and Bambara groundnut flour contain a lot of moisture (Da Silva *et al.*, 2016). The increase in moisture content of pasta by addition of composite flour was also noted by Hussin *et al.*, (2020) after adding composite flour of Bambara groundnut and Moringa into the pasta using the ratio of 80:20 wheat and Bambara groundnut flour, and 94:6 wheat and Moringa flour.

Table 4: Proximate composition of pasta

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrates (%)	Fibre (%)
W100	8.55 ± 0.05 ^a	1.34 ± 0.02 ^a	9.28 ± 0.14 ^a	0.67 ± 0.02 ^a	77.47 ± 0.18 ^a	0.58 ± 0.18 ^a
W90O5B5	9.80 ± 0.44 ^b	3.60 ± 0.13 ^b	9.58 ± 0.07 ^b	2.06 ± 0.03 ^b	76.08 ± 0.18 ^b	1.81 ± 0.15 ^b
W70O15B15	10.12 ± 0.55 ^b	4.10 ± 0.03 ^c	9.71 ± 0.11 ^b	2.07 ± 0.04 ^b	75.78 ± 0.12 ^c	1.90 ± 0.23 ^{bc}
W50O25B25	11.13 ± 0.18 ^c	4.38 ± 0.06 ^d	9.73 ± 0.08 ^b	2.15 ± 0.06 ^c	74.61 ± 0.14 ^d	2.27 ± 0.23 ^c

Values are mean ± standard deviation of triplicate determination. Means with the same superscripts within the same column are not significantly different ($P \geq 0.05$). W100 = (100% wheat flour); W90O5B5 = (90:5:5 semolina, OFSP and Bambara groundnut flour); W70O15B15 = (70:15:15 semolina, OFSP and Bambara groundnut flour); W50O25B25 = (50:25:25 semolina, OFSP and Bambara groundnut flour).

Moisture content determination in food products is important for legal and labeling requirements, microbial stability and processing operations require knowledge of moisture content during mixing, drying, packaging and storage (Moulvaney and Cunniff, 2009; Duda *et al.*, 2019). The amount of moisture in food affects its texture, taste, appearance, and stability; also, the propensity of microorganisms to develop in meals is influenced by its moisture level (Isengard, 2001; Sato *et al.*, 2018).

The addition of OFSP and Bambara groundnut flour to pasta resulted in a significant ($P < 0.05$) increase in ash content, ranging from 1.34% to 4.38%. The lowest ash content was found in sample W100 while the highest ash content was found in sample W90O5B5. The findings also revealed that increasing the amount of OFSP and Bambara groundnut flour in the pasta enhanced

the ash concentration. Jolgaonkar and Jha (2016) found that adding pearl millet to semolina raised the ash content of dry pasta from 0.47% to 1.03%. Because ash is responsible for pasta discolouration, a low ash level in flour is advantageous for pasta (Jolgaonkar and Jha, 2016; Palavecino *et al.*, 2017).

Protein levels in pasta increased from 9.28% to 9.73% after fortification. Sample W100 differed significantly ($P < 0.05$) from the rest of the samples (W90O5B5-W50O25B25) which had no significant differences between them. The use of Bambara groundnut flour in the pasta can increase protein levels (Awolu and Oseyemi, 2016). Da Silva *et al.*, (2016) found no difference between proteins of all treatments because OFSP and Bambara groundnut starch are essentially starch raw material. The low protein profile of pasta made from wheat was enhanced, as higher protein contents were obtained with the inclusion of OFSP and Bambara groundnut.

The results for fat content ranged from 0.67% to 2.15%. There was no significant difference ($P > 0.05$) between sample W90O5B5 and W70O15B15. Sample W50O25B25 had the highest fat content, whereas sample W100 had the lowest fat content. The fat content of samples containing OFSP and Bambara groundnut was considerably greater. An increase in fat content may result from the composition of pasta with Bambara groundnut flour which consists of high amounts of fat (Abu-Salem and Abou-Arab, 2011). Effiong *et al.*, (2018) found lower fat content levels ranging from 0.7% to 8.3% compared to the results obtained by Omeire *et al.*, (2014). Low fat content of pasta is beneficial to human health because it may reduce the pace at which cholesterol is formed in the body (Effiong *et al.*, 2018).

Pasta had a carbohydrate content ranging from 74.61% to 77.47%. All pasta samples were significantly different ($P < 0.05$) from one another. The highest carbohydrate content was found in sample W100, while the lowest carbohydrate content was found in sample W50O25B25. These findings revealed that as wheat flour quantity was reduced, the carbohydrate content of pasta samples decreased. Olumbunmi *et al.*, (2017) and Abu-Salem and Abou-Arab (2011) indicate that the decrease in carbohydrates is likely caused by the fortification of pasta with orange fleshed sweet potato flour which has a low amount of carbohydrates (65.45%) and low amount of Bambara groundnut (68.00%) compared to carbohydrates found in wheat flour (84.60%). Bashir *et al.*, (2012) achieved similar results, reporting that the composite flour of pasta increases protein, fat, ash, and fibre content while decreasing carbohydrate content compared to the control (Carcea *et al.*, 2017).

The study findings showed that value fibre increased three to four fold by addition of OFSP and Bambara groundnut. Sample W100 contained 0.58% fibre compared to 1.81 to 2.27% for composite samples. Between samples W90O5B5 and W70O15B15, there was no significant difference ($P > 0.05$), and between samples W70O15B15 and W50O25B25 there was no significant difference ($P > 0.05$). The maximum fibre content was found in Sample W50O25B25 at 2.27%. The fibre content of wheat pasta was improved considerably by adding OFSP and Bambara groundnut. Vital *et al.*, (2020) also obtained an increase of fibre content of pasta from the addition of composite flour. Elleuch *et al.*, (2011) states that irritable bowel syndrome, cancer, and diabetes are all disorders that can be prevented by eating enough fibre. Eating a high-fibre diet softens stools and lowers plasma cholesterol levels in the body (Norman and Joseph, 1995; Olubunmi *et al.*, 2017).

4.2 Functional properties

Table 4 compares the functional qualities of several pastas made with different ratios. Particle size and flour density determine bulk density which is significant in determining packing requirements and material handling. The bulk density values ranged from 0.32g/ml to 0.48g/ml. The bulk density of all samples increased significantly with the addition of composite flour (OFSP and Bambara groundnut flour). Sample W50O25B25 had the highest bulk density of 0.48g/ml compared to the other samples, whereas Sample W100 had the lowest bulk density (0.32g/ml) compared to other samples.

Table 5: Functional properties of pasta

Sample	Bulk density (ml/g)	Water absorption capacity (ml/g)	Oilabsorption capacity (ml/g)	Swelling Index (ml/g)
W100	0.32 ± 0.01 ^a	1.25 ± 0.04 ^a	0.59 ± 0.05 ^a	2.80 ± 0.30 ^a
W90O5B5	0.33 ± 0.02 ^b	1.12 ± 0.03 ^b	0.43 ± 0.03 ^b	2.56 ± 0.17 ^a
W70O15B15	0.36 ± 0.02 ^c	0.81 ± 0.06 ^c	0.31 ± 0.04 ^c	1.96 ± 0.48 ^a
W50O25B25	0.48 ± 0.01 ^d	0.73 ± 0.09 ^c	0.30 ± 0.03 ^c	2.27 ± 0.85 ^a

Values are mean ± standard deviation of triplicate determination. Means with the same superscripts within the same column are not significantly different ($P \geq 0.05$). W100 = (100% wheat flour); W90O5B5 = (90:5:5 semolina, OFSP and Bambara groundnut flour); W70O15B15 = (70:15:15 semolina, OFSP and Bambara groundnut flour); W50O25B25 = (50:25:25 semolina, OFSP and Bambara groundnut flour).

Awolu *et al.*, (2017) states that the high bulk density value improves dispensability while also reducing pasta thickness. Omeire *et al.*, (2014) reported similar results, claiming that using composite flours enhanced bulk density. The increase in bulk may be useful in product packaging since it takes up less space and may also be advantageous in solubility as the particles have less tendency of floating during soaking in liquid prior to consumption, which could also improve digestion (Ayo *et al.*, 2014; Ahmad *et al.*, 2018; Kumar *et al.*, 2022).

The water absorption capacity (WAC) of pasta ranged from 0.73 ml/g to 1.25 ml/g. Sample W70O15B15 and W50O25B25 had no significant difference in WAC ($P > 0.05$), however sample W100 had a higher value than other samples and sample W50O25B25 had the lowest value than other samples. The findings showed that the combination of OFSP and Bambara groundnut flour results in a significant decrease in WAC. The absence of gluten in both OFSP and Bambara groundnuts may account for the low WAC levels (Omeire *et al.*, 2014; Tan *et al.*, 2020). Iwe and Onadipe (2001) point out that the ability of flour to absorb water boosts dough making potentials.

Olubunmi *et al.*, (2017) note that the oil absorption capacity (OAC) is a measurement of the rate at which protein binds to fat in food formulations and is primarily due to physical trapping of oils. The OAC of pasta changed considerably by adding OFSP and Bambara groundnut flour. The OAC of pasta ranged from 0.30 ml/g to 0.59 ml/g. There was no significant difference in OAC between samples W70O15B15 and W50O25B25 ($P > 0.05$). Sample W100 showed the highest oil absorption capacity of 0.59 ml/g whereas sample W50O25B25 showed the lowest OAC of 0.30 ml/g. The results showed that OAC was decreasing with the increase of supplementation of composite flour into the pasta. Similarly, Omeire *et al.*, (2014) found that wheat pasta had the maximum oil absorption capacity of 1.94 ml/g and was substantially different ($P > 0.05$) from composite pasta. Shukla and Srivastava (2014) notes that OAC improves pasta's tongue feel and with the retention of flavour.

Pasta had a swelling index ranging from 1.96 ml/g to 2.80 ml/g. The swelling index data revealed no significant differences ($P > 0.05$) across the samples. The maximum swelling index was 2.80 ml/g, whereas the lowest swelling index was 1.96 ml/g in sample W70O15B15. The results showed that as the level of composite flour substitution was increased, the swelling index decreased. The observed decrease in swelling index could be attributable to a decrease in starch gelatinization in the pasta when cooking time increases in tandem with starch content decrease.

Gopalakrishnan *et al.*, (2011) indicates that the addition of non-wheat ingredients like OFSP and protein sources like Bambara groundnut flour may cause gluten dilution and low swelling in

enhanced pasta compared to durum semolina pasta, implying that the added proteins may be competing with starch for water. Julianti *et al.*, (2017) also states that the swelling index indicates how much water the starch granules in the flour absorb.

4.3 Vitamins

Table 5 shows the vitamin content of the pasta samples. The vitamin C content of the pasta ranged from 8.65 mg/100g to 8.93 mg/100g. Vitamin C levels differed significantly ($P < 0.05$) among the composite samples (W90O5B5, W70O15B15 and W50O25B25). Sample W50O25B25 had the highest vitamin C content (8.93 mg/100g), while sample W90O5B5 had the lowest vitamin C content (8.65 mg/100g).

Table 6: Vitamins A and Vitamin C of composite pasta

Sample	Vitamin C (mg/100g)	Vitamin A (mg/100g)
W90O5B5	8.65 ± 0.08 ^a	1.28 ± 0.01 ^a
W70O15B15	8.71 ± 0.01 ^b	1.56 ± 0.02 ^b
W50O25B25	8.93 ± 0.22 ^c	1.95 ± 0.06 ^c

Values are mean ± standard deviation of triplicate determination. Means with the same superscripts within the same column are not significantly different ($P \geq 0.05$). W100 = (100% wheat flour); W90O5B5 = (90:5:5 semolina, OFSP and Bambara groundnut flour); W70O15B15 = (70:15:15 semolina, OFSP and Bambara groundnut flour); W50O25B25 = (50:25:25 semolina, OFSP and Bambara groundnut flour).

Findings indicate that the value of vitamin C in pasta increases with the increase in composite flour. Vitamin C is an important and necessary nutrient for humans, and it can be used to determine the quality of nutrients during processing. Ascorbic acid is most sensitive to oxygen, light, temperature, metal ion catalysis, and its retention depends on the processing conditions and duration (Stephen *et al.*, 2017; Alam *et al.*, 2020).

Vitamin A content of pasta ranged from 1.28 mg/100g to 1.95 mg/100g. As expected, the results revealed a significant difference ($P < 0.05$) between all samples, with sample W50O25B25 having the highest vitamin A value (1.95 mg/100g) and sample W90O5B5 having the lowest vitamin A value (1.28 mg/100g). As the fortification increased, the amount of vitamin A in pasta increased as well. Vitamin A is abundant in pasta containing OFSP flour. Despite being treated to various processing procedures such as blanching and drying, as well as storage, it can maintain beta-carotene which determines the amount of vitamin A present in the pasta.

Vitamin A is necessary for growth and development, as well as the maintenance of the immune system and vision (Mepha *et al.*, 2007; Tanumihardjo, 2011). WHO (2009) states that Vitamin A deficiency causes stunted growth and development, night blindness and even total blindness, illness susceptibility, and in severe cases, death. Giving vitamin A to patients who are deficient in the vitamin lowers the severity of infections like influenza and diarrhea, as well as baby and maternal mortality by roughly 30% (Beaton *et al.*, 1993; Black *et al.*, 2008; Sule and Abu, 2017).

4.4 Cooking quality

Table 6 shows the quality of pasta cooked using different ratios of ingredients. Compared to the control sample, the cooking time of the samples containing OFSP and Bambara groundnut were significantly higher, ranging from 12.7 minutes to 22.3 minutes. This was longer than wheat pasta sold commercially (Surasani *et al.*, 2019). Cooking the dried seed takes a long time, work, and fuel and this is a barrier to its greater use. For example, fresh beans may take 45-60 minutes to boil, while dry beans may take 3-4 hours. The incorporation of Bambara groundnut flour with semolina may result in increased cooking time. Similar results were obtained by Guo *et al.*, (2018), who explained that when legume flour is added to wheat flour, the protein compete with wheat proteins and starch for water, decreasing their hydration.

Lawal *et al.*, (2021) points out that the prolonged cooking time of composite pasta is most likely due to starch structural changes. According to Kulkarni *et al.*, (2020) the optimal cooking time of the pasta is generally influenced by the rate of water movement in pasta and subsequent starch gelatinization. The slow hydration of starch require a longer cooking time for its gelatinization (Guo *et al.*, 2018). These findings corroborated those of da Silva *et al.*, (2016) and Bashir *et al.*, (2012) who found that the cooking time rose in proportion to the OFSP level (up to 75.8%), and that the cooking time of the pasta sample was considerably longer than the control.

Table 7: Cooking quality of pasta

Sample	Time (min)	Cooking loss (%)	Texture (kgf)
W100	12.66 ± 0.58 ^b	7.67 ± 3.79 ^a	0.27 ± 0.03 ^a
W90O5B5	16.00 ± 2.65 ^b	13.67 ± 3.21 ^b	0.22 ± 0.02 ^b
W70O15B15	20.67 ± 3.51 ^a	14.00 ± 2.64 ^b	0.18 ± 0.02 ^{bc}
W50O25B25	22.33 ± 0.58 ^a	17.00 ± 1.73 ^b	0.16 ± 0.01 ^c

Values are mean ± standard deviation of triplicate determination. Means with the same superscripts within the same column are not significantly different ($P \geq 0.05$). W100 = (100% wheat flour); W90O5B5 = (90:5:5 semolina, OFSP and Bambara groundnut flour); W70O15B15 = (70:15:15 semolina, OFSP and Bambara groundnut flour); W50O25B25 = (50:25:25 semolina, OFSP and Bambara groundnut flour).

The cooking loss of pasta ranged from 7.6% to 17.00%. Cooking loss values obtained from pasta containing OFSP-Bambara groundnut were significantly higher ($P > 0.05$) than those obtained from wheat pasta. Brennan *et al.*, (2004) observed a cooking loss of 7.93% for commercial pasta (Surasani *et al.*, 2019). Cooking loss of up to 6% is typical of very good pasta, up to 8% is typical of average-quality pasta and values of equal to or greater than 10% are typical of poor-quality pasta (Sato *et al.*, 2018). An increase in cooking loss may result from an increase in fibre materials of the composite flour of OFSP and Bambara groundnut. According to Noorfarahzilah *et al.*, (2014), a partial or complete substitution of wheat semolina with materials that are rich in fibre can result in negative changes to pasta quality, including increased cooking loss. When composite flour is mixed with wheat flour to make pasta, the cooking loss increases. Gopalakrishnan *et al.*, (2011) found similar results, with the greatest value of cooking loss for fish powder fortification in pasta ranging from 12% to 16%. Gopalakrishnan *et al.*, (2011) states that the greater cooking loss, is caused by the disturbance of the protein starch network. This could be because non-gluten flour is used instead of wheat flour, weakening the pasta network that holds the starch particles together.

The textural properties of pasta are crucial in determining whether it will be accepted by consumers. The textural quality of the cooked pasta ranged from 0.16 kgf to 0.27 kgf. The addition of composite flour to the pasta dramatically changed the texture and interfered with the structure of the pasta, resulting in a lower pasta texture. Similar results were observed by Reungmanee-paitoon (2009) who found that instant fried noodles made with sweet potato flour had significantly less tensile power than wheat noodles. The tensile force decreases as the percentage of cooked sweet potato flour increases from 20% to 40% of the total composite flour ($P > 0.05$).

Because gluten protein content is one of the most important quality parameters influencing pasta quality, an increase in protein content degrades the product in terms of cooking loss and hardness value (Noorfarahzilah *et al.*, 2014).

4.5 Colour measurements

The colour of the pasta is an important quality factor for consumers. The results of colour measurements of pasta are shown in Table 7. No significant difference ($P > 0.05$) was found between sample W100, W90O5B5 and W50O25B25; and sample W70O15B15 and W50O25B25 in the L^* value of the pasta ranged from 70.61 to 77.95. The findings about colour revealed that the L^* parameter, which is directly related to the lightness of the pasta, increases as the amount of composite flour in the pasta increases. There was no significant difference ($P > 0.05$) found between sample W100, W90O5B5 and W70O15B15 in a^* value ranging from 0.00 to 0.52; however, sample W50O25B25 was different from other samples. With the addition of composite flour to the pasta, the results of a^* parameter increased. Sample W50O25B25 had the greatest value of a^* , while sample W100 had the lowest.

The degree of yellowness (b^*) ranged from 18.61 to 27.36. Sample W100 which is 100% wheat pasta was different from other samples regarding b^* value, however, no significant differences were found in sample W90O5B5, W70O15B15 and W50O25B25. Sample W70O15B15 had the greatest b^* value, while sample W100 had the lowest. The high value of yellowness (b^*) in sample W50O25B25 may be due to the presence of OFSP flour in to the pasta. Yellowness and brightness are correlated both to the pigment concentration and non-enzymatic browning (Doxastakis *et al.*, 2007).

Chroma value (C^*) ranged from 188.74 to 27.48. Sample W100 differed significantly ($P < 0.05$) from the other samples W90O5B5, W70O15B15, and W50O25B25, which revealed no significant differences. Sample W70O15B15 had the greatest C^* value, while sample W100 had the lowest. The results showed that an increase in composite flour (OFSP and Bambara groundnut flour) increases the Chroma value C^* . Chroma (C^*) notation indicates the quality of a colour's purity, intensity or saturation.

Hue angle (h^0) is the common distinction between colours positioned around a colour wheel. The results obtained showed a significant decrease ($P < 0.05$) in the values of h^0 and ΔE which ranged from 88.90 to 96.67 and 1.98 to 8.76 respectively. The h^0 and ΔE values decreased as the incorporation of pasta with composite flour (OFSP and Bambara groundnut) increased.

The findings corroborated with those of Kim (2006) who found that the b^* value increased with a decrease in h^0 and the a^* value increased with an increase in h^0 . The difference between the presented parameters is associated to the different ingredients used. The colour of a product is an important quality parameter that is strongly linked to the product's consumer acceptability. Increases in composite flour caused uncooked pasta to change colour. The more composite flour was added, the more noticeable the changes in colour of pasta.

4.6 Consumer acceptability

Table 8 presents the results of a sensory evaluation conducted by 100 untrained panelists on the consumer acceptability of pasta. The visual quality of a product is its appearance. The average appearance score ranged from 4.51 to 5.56.

Table 8: Colour measurement of pasta

Samples	L*	a*	b*	C*	h ^o	ΔE
W100	70.61 ± 4.40 ^a	0.00 ± 0.00 ^a	18.61 ± 0.94 ^a	18.74 ± 0.94 ^a	96.67 ± 0.31 ^a	8.76 ± 0.27 ^a
W90O5B5	70.66 ± 3.21 ^a	0.09 ± 0.05 ^a	25.63 ± 1.23 ^b	25.63 ± 1.23 ^b	89.86 ± 0.58 ^b	3.92 ± 0.57 ^b
W70O15B15	77.95 ± 1.28 ^b	0.13 ± 0.22 ^a	27.47 ± 1.36 ^b	27.48 ± 1.36 ^b	89.82 ± 0.10 ^b	2.96 ± 0.63 ^c
W50O25B25	75.74 ± 0.89 ^{ab}	0.52 ± 0.14 ^b	27.36 ± 0.34 ^b	27.37 ± 0.35 ^b	88.90 ± 0.27 ^c	1.98 ± 0.66 ^d

Values are mean ± standard deviation of triplicate determination. Means with the same superscripts within the same column are not significantly different ($P \geq 0.05$). W100 = (100% wheat flour); W90O5B5 = (90:5:5 semolina, OFSP and Bambara groundnut flour); W70O15B15 = (70:15:15 semolina, OFSP and Bambara groundnut flour); W50O25B25 = (50:25:25 semolina, OFSP and Bambara groundnut flour).

Table 9: Consumer acceptability of pasta

Samples	Appearance	Colour	Taste	Mouthfeel (cohesive- ness)	Chewiness (texture)	Hardness	Overall Acceptability
W100	5.56 ± 2.26 ^a	6.37 ± 2.00 ^a	4.60 ± 1.75 ^a	5.54 ± 1.65 ^a	5.67 ± 1.55 ^a	5.71 ± 1.65 ^a	5.64 ± 2.43 ^a
W90O5B5	4.51 ± 1.92 ^b	5.34 ± 1.96 ^b	3.43 ± 1.37 ^b	5.14 ± 2.34 ^b	5.13 ± 2.49 ^b	5.44 ± 2.42 ^b	3.84 ± 1.95 ^b
W70O155	4.66 ± 1.92 ^b	5.37 ± 2.33 ^b	6.91 ± 1.50 ^c	4.35 ± 1.92 ^c	4.48 ± 1.87 ^c	4.83 ± 1.99 ^c	6.97 ± 1.61 ^c
W50O255	4.74 ± 1.79 ^b	3.91 ± 2.10 ^c	5.53 ± 2.03 ^d	3.33 ± 1.29 ^c	3.71 ± 1.97 ^c	3.73 ± 1.98 ^d	4.50 ± 2.22 ^a

Values are mean ± standard deviation of triplicate determination. Means with the same superscripts within the same column are not significantly different ($P \geq 0.05$). W100 = (100% wheat flour); W90O5B5 = (90:5:5 semolina, OFSP and Bambara groundnut flour); W70O15B15 = (70:15:15 semolina, OFSP and Bambara groundnut flour); W50O25B25 = (50:25:25 semolina, OFSP and Bambara groundnut flour). Scale: 1 = extremely dislike to 9 = extremely like.

In terms of appearance, there was a significant difference ($P > 0.5$) between the control (sample W100) and treatments sample (W90O5B5, W70O15B15, and W50O25B25), although no significant difference ($P > 0.05$) was found between sample W90O5B5 and sample W70O15B15. The mean value of sample W100 pasta was the highest, while the mean value of sample W90O5B5 pasta was the lowest.

Consumers utilize colour as the first sensory feature to assess food desirability (da Silva *et al.*, 2016). Pasta colour values ranged from 3.91 to 6.37. For colour, there was a significant difference ($P < 0.05$) across samples; however, there was no significant difference ($P > 0.05$) between samples W90O5B5 and W70O15B15. The maximum colour value was in sample W100, while the lowest colour value was in sample W50O25B25. Da Silva *et al.*, (2016) argues that consumers are influenced by colour because it can be used as a freshness indicator.

The mean score for taste ranged from 3.43 to 6.91. There was a significant difference ($P < 0.05$) between the samples, with sample W70O15B15 pasta having the greatest mean value for taste and sample W90O5B5 pasta having the lowest mean value. The results showed an increase in taste with the increase in pasta produced from composite flour.

The mean values for mouth feel (cohesiveness), chewiness (texture) and hardness ranged from 3.33 to 5.54, 3.71 to 5.67 and 3.73 to 5.71, respectively. For each of these parameters all samples showed significant differences ($P < 0.05$). The highest values for mouth feel, chewiness (texture) and hardness were found in sample W100 pasta while the lowest values were found in sample W50O25B25 pasta.

The results for overall acceptability of pasta ranged from 3.84 to 6.97. Sample W100 and W50O25B25 showed no significant difference between each other. Sample W70O15B15 had the highest mean value (6.97) for overall acceptability, while sample W90O5B5 had the lowest mean value (3.84) for overall acceptability. Since all pasta samples were moderately liked by consumers for all sensory parameters, it can be recommended that fortification of up to 25% of composite flours in wheat pasta could be used in the production of pasta product.

The composition of wheat pasta with 70:15:15 semolina, OFSP and Bambara groundnut flour is recommended as it was the most preferred product for good taste and consumer acceptability during testing as compared to the composition of pasta with 90:5:5 semolina, OFSP and Bambara groundnut flour; 50:25:25 semolina, OFSP and Bambara groundnut flour and pasta produced from 100% wheat flour.

CHAPTER 5: CONCLUSIONS

In order to improve the quality properties of pasta, the study looked into the possibility of utilizing composite flour made from orange-fleshed sweet potatoes and Bambara groundnuts. Pasta formulations containing OFSP-Bambara groundnut composite flour have shown to significantly improve a number of quality Parameters. The research has shown that this innovative approach can lead to improvements in sensory attributes such as colour, taste, and texture. Moreover, the composite flour has the potential to enrich pasta with essential nutrients, including vitamins, proteins, and dietary fiber, contributing to its nutritional value.

Composite flour shows good potential for use as a the functional agent in pasta products, therefore more evaluation of the functionality of composite flour in pasta making should be performed to ensure an increase in the use of composite flour made from many different raw materials in future. Moreover the development and consumption of food made from composite flour not only improves the nutritional status of the general population but also helps those suffering from certain diseases associated with today's changing lifestyles and environment. The diet which is high in complex carbohydrates and high protein made from composite flour of legumes like Bambara groundnut and vegetables like orange-fleshed sweet potato can lower the risk of diseases like diabetes, hypertension, cardiovascular diseases and obesity.

The inclusion of sweet potato flour in pasta can potentially reduce its glycemic index (GI). Sweet potatoes have a lower GI compared to wheat flour, which means they cause a slower and more gradual increase in blood sugar levels when consumed. When sweet potato flour is used to make pasta, it adds a source of complex carbohydrates and dietary fiber. When compared to pasta prepared only from wheat flour, these components can help slow down the digestion and absorption of carbohydrates. For those trying to control their blood sugar levels or find a lower-GI alternative to typical wheat pasta, adding sweet potato flour can be a good choice.

From the overall results, it could be concluded that the composite flour of OFSP and Bambara groundnut increases the proximate composition (moisture, protein, fats, fibre and ash) of pasta compared to pasta made entirely of wheat. The addition of the composite flour (OFSP and Bambara groundnut) in pasta significantly affected the cooking quality of pasta causing an increase in the cooking time and cooking loss values. However, the composite flour positively contributed to the increase in proximate composition of pasta wherein pasta with the blend of 50:25:25 semolina, OFSP and Bambara groundnut flour showed a high value of protein, vitamin C and vitamin A which can be appropriate for better nutritional benefits of composite pasta.

The high value of vitamin A in OFSP-Bambara groundnut pasta would be very useful in alleviating vitamin A deficiency among children years and adults. In countries where malnutrition poses a serious problem especially among children, pasta with the blend of 70:15:15 semolina, OFSP and Bambara groundnut flour and consequent better nutritional quality (high value of protein, vitamin A and Vitamin C), would be highly desirable. A good quality protein consists of surplus lysine and higher amount of methionine which are present in Bambara groundnut. High content of fibre found in OFSP-Bambara groundnut pasta may help to maintain bowel health of the consumers, lowers cholesterol levels and normalizes bowel movements, it is also important in the prevention of several diseases such as irritable colon, cancer and diabetes.

The colour of the product plays an important role which is strongly influence the consumer acceptability of the product, hence an increase in yellowness (b^*) of OFSP-Bambara groundnut pasta has a good appealing colour which can easily influence consumer's acceptance of the product. The development of appealing processed pasta from composite flour of OFSP and Bambara groundnut will therefore play a major role in raising awareness on the potential of the crops.

Furthermore, it could be concluded that a blend composition of 70:15:15 semolina, OFSP and Bambara groundnut flour may be utilized to make pasta of acceptable quality as it improved sensory qualities compared to pasta made entirely of wheat flour. The study shows that a high ratio of composite flours negatively affects the cooking quality of pasta, consequently the over cooking of the pasta product in boiling water should be avoided. More research is needed on the cooking qualities of pasta made from composite flours and new investigations can include development of more pasta products for domestic markets. In addition, the price of composite pasta needs to be determined.

The reduction in dependence on wheat flour through the utilization of composite flour made from Bambara groundnut and sweet potato to produce pasta is a promising innovation. The pasta is made into a greater source of important nutrients by adding Bambara groundnut and sweet potato. This decrease in reliance on wheat flour is in line with initiatives to promote sustainable agriculture, diversify food sources, and serve a larger consumer base with a range of dietary needs and tastes. Further research and development in this direction hold significant potential for creating healthier and more sustainable pasta products.

In addition, the study has highlighted the importance of optimizing the blending ratios and processing parameters to achieve the desired sensory and nutritional characteristics. This

suggests that further research and development efforts are needed to fine-tune the formulation and production processes for orange fleshed OFSP-Bambara groundnut composite pasta on an industrial scale. The findings underscore the potential socio-economic benefits of incorporating locally available and underutilized crops like OFSP and Bambara groundnut into staple food products such as pasta. This can not only create new income opportunities for farmers but also contribute to addressing malnutrition and food security challenges, particularly in regions where these crops are abundant.

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APPENDIX

Appendix 1: Sensory scorecard

Panelist # _____

Pasta Panel Questionnaire

Personal Info

1. Sex

Male

Female

2. Age

<20

21-30

31-40

41-50

51-60

>61

Health

1. Do you have any food allergies? If so, please list.

2. Do you take any medications, which may affect your senses, especially taste and smell?

3. Are you currently on a restricted diet? If so, please explain.

Eating Habits

1. How often do you consume pasta per week?

0

1-3

4-6

>7

Consumer Acceptability Panel

9-Point Hedonic Scale

Name:

date:.....

Instructions:

1. You are presented with three coded sample
2. Evaluate each sample for the below attribute by cross (X)/ cycling on corresponding number (1= extremely dislike, 2= very dislike, 3= dislike, 4= slightly dislike 5= not sure, 6= slightly like, 7= like, 8= very like, 9= extremely like)
3. Cleanse a pallet (mouth) with water after each sample

APPEARANCE

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401									

COLOUR

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401									

TASTE

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401									

MOUTH FEEL (COHESSIVENESS/ROUGH)

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401									

CHEWINESS (TEXTURE)

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401..									

HARDNESS

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401									

OVERALL ACCEPTABILITY

	1	2	3	4	5	6	7	8	9
Sample 101									
Sample 201									
Sample 301									
Sample 401									

Would you be willing to buy one of the following samples?

Sample 101 YES NO UNSURE

Sample 102 YES NO UNSURE

Sample 103 YES NO UNSURE

Comments:

.....
.....
.....

.....Additional Comments/ Suggestions: (here we would appreciate any comments/suggestions you have. Some of the samples you tasted were made from a mixture of Sweet Potato Flour and Bambara Groundnut Flour).

Thank you for your comments!

We hope you enjoyed yourself and had fun in the Pasta Education Program!