EVALUATION OF QUALITY PROPERTIES OF BREAD PRODUCED FROM WHEAT (*Triticum aestivum)*, CASSAVA (*Manihot esculenta*) AND BAMBOO SHOOT(*Yushania alpina*) COMPOSITE FLOURS

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DECLARATION AND RECOMMENDATION

Declaration

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

Signature…… ………………. Date…24/04/2023……………….

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Recommendation

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

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DEDICATION

I dedicate this work to my family - my mother, Marceline Nyamayi and friends.

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ABSTRACT

The need to combat food insecurity and malnutrition has seen industries focus on enriching indigenous staple foods with locally available nutritious underutilised food crops. Bamboo shoots (*Yushania alpina*) have drawn significant global interest owing to their high nutritional content, low fat and health-promoting compounds. This study evaluated the composite flours for rheological properties and the wheat (*Triticum aestivum)*, cassava (*Manihot esculenta)*, bamboo shoot (BS) composite bread for physicochemical, microbial, and sensory properties. Five levels of BS (0, 2.5, 5, 7.5, and 10%) were substituted for wheat-cassava using an 80:20 percent wheat: cassava mixture as control. The flours were analysed for water absorption, normal falling number, dough stability and dough softening. Bread samples were baked from the formulated composite flours and analysed for physical, nutritional, microbial, and sensory properties. Water absorption increased with an increase in BS substitution, whereas there was a reduction of 16.8% in the normal falling number. Dough softening increased with an increase in BS inclusion up to 7.5%. All the bread made from BS flour had significantly different ($p < 0.05$) physical properties (loaf volume, density, specific volume, and Browning Index) from the control. Bamboo shoots had 16.6% ash, 19.7% fibre, 29.4% crude protein, and the lowest energy-to-protein ratio of 9.78 kcal/g. The proximate components of the blended bread increased with an increase in BS substitution. Composite flour with 10% BS had the highest total ash, crude fibre, and protein at 4.51%, 5.26%, and 26.4% compared to control, which had 0.66%, 0.88%, and 1.55%, respectively. The total viable counts ranged from 2.62 cfu/g to 3.67 cfu/g, while the total coliform ranged from 1.43 cfu/g to 2.97 cfu/g and yeast and mould counts from 2.89 cfu/g to 3.59 cfu/g. *Escherichia coli* was not detected in the bread samples. The Principle Component Analysis showed the existence of 3 principle components that explained a total variation of 78.5%, with crumb colour, density, aroma, aftertaste, stickiness, grittiness, cohesiveness, and chewiness as predominant factors. However, 2.5% BS flour bread had no significant difference ($p > 0.05$) in taste, aroma, crumb colour, crust colour, and overall acceptability compared to the control. Results of this study show that BS flour can be blended with wheat-cassava composite to increase BS utilization and improve the nutritional value of developed products, thus providing diversification in bakery products.

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LIST OF ABBREVIATIONS AND ACRONYMS

AACC	Association of American Cereal Chemists
ADF	Acid detergent fibre
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
BS	Bamboo shoot
CESAAM	Centre of Excellence in Sustainable Agriculture and Agribusiness Management
CFU	Colony forming units
CNP	Cyanogenic potential
CRD	Completely Randomized Design
CTA	Cassava Transformation Agenda
DRI	Dietary Reference Intake
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GoK	Government of Kenya
HCN	Hydrocyanic acid
HDPE	High Density Polyethylene bags
HQCF	High-Quality Cassava Flour
KALRO	Kenya Agriculture and Livestock Research Organization
NA	Nutrient Agar
NDF	Neutral detergent fibre
NFN	Normal Falling Number
PCA	Principle Component Analysis
PDA	Potato Dextrose Agar
SSA	sub- Saharan Africa
TVC	Total viable count
UNICEF	United Nations Children’s Fund
USDA	United States Department of Agriculture
WB	World Bank Group

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Food insecurity and malnutrition are challenging global health concerns despite considerable progress in increasing global food production over the past centuries. Food insecurity is the inability to access safe, sufficient, nutritious food. Approximately one billion people (16% of the global population) are food insecure and suffer from chronic hunger due to insufficient nutritionally balanced food (McCarthy *et al.*, 2018). The vast majority of chronically hungry and malnourished people are from developing countries. In sub-Saharan Africa (SSA), the number of people suffering from hunger is about 239 million, with Eastern Africa having the highest prevalence (Sasson, 2012). In Kenya, about 8.8 million people are undernourished, with 40% of the population living in poor urban settlements (UNICEF/WHO/WB, 2017). Food insecurity, hunger, and malnutrition have been accelerated by over-reliance on a few staple foods, unpredictable weather patterns, and climate change. In developing countries, heavy reliance on staple cereals like wheat, rice, corn, millet, and sorghum has promoted nutritional, economic, agronomic, and ecological implications (Ebert, 2014).

Despite wheat (*Triticum aestivum)* being a staple food crop in Africa, it remains the world's largest importer accounting for 60% of its wheat consumption. The increase in wheat consumption in SSA has been observed during the past 20 years owing to increasing populations, urbanization influencing socio-economic changes, and changing food preferences (Mwobobia *et al.*, 2020). Kenya's consumption has spiked but cannot be met as it only produces 40% of its national wheat requirement (Wambua, 2017). Wheat is normally used in making baked products like bread, thus contributing 50.4% of consumer dietary requirements (Kearney, 2010). Wheat application in bread making is attributed to its viscoelastic network due to gluten (Ohimain, 2014). Currently, most countries use other locally grown cheap crops to meet the demand for bread. These crops include; cassava, sorghum, chickpea, and soybean to substitute wheat flour partially or fully. Out of these, cassava has great potential since it is a climate-smart crop with good flour properties.

Cassava (*Manihot esculenta*) root is inexpensive and readily available and can grow in a wide range of agro-ecologies (Parmar *et al.*, 2017). As a cheap energy-dense food, cassava's global production is about 225 million, consumed by over 200 million people as a staple crop.

In Kenya, cassava is grown in the Western, Eastern, Coastal, and Central regions. *Selele* variety is a local variety preferred by farmers and consumers in Western Kenya because it is drought tolerant, easy to cook, and tastes better than other improved varieties (Odhiambo, 2018). Studies have shown that its application in bread baking resulted in bread of high specific volume and form ratio and better sensory properties (Wambua, 2017). Partial substitution of wheat with cassava flour in baking can be achieved through compositing. Research is currently centred on composite flours comprising tubers, cereal, and legumes as a possible replacement for wheat flour (Awolu & Oseyemi, 2016; Bamigbola *et al.*, 2016).

Countries like Nigeria have successfully incorporated cassava flour into wheat for baking with up to 10% cassava inclusion (Guira *et al.*, 2017). Compositing wheat and cassava might allow for diversification and increased utilization. However, the nutritional deficit remains as refining wheat during processing reduces its protein, dietary fibre, minerals, and vitamins (Oghbaei & Prakash, 2016). On the other hand, cassava has the lowest protein energy ratio, where most cultivars have a protein content of only 1%. Due to these deficiencies, an alternative source of nutrients is required to enrich the wheat-cassava composites. Nutrient-rich and underutilised crops or vegetables like bamboo shoots are increasingly gaining recognition as alternative crops (Wang *et al*., 2020).

Bamboo (*Yushania alpina*) shoots are young culms of bamboo plants containing exceptionally high nutrients, including proteins (33.4 g/100g), dietary fibre (23.9-30.7 g/100g), carbohydrates (17.3-23.6 g/100g), minerals (13.67 g/100g), and vitamins (Karanja, 2017). The shoots are also rich in nutraceuticals like phytosterols and phenols (Nirmala *et al*., 2018). *Yushania alpina* is an indigenous species that grows in most Kenyan highlands. The phenolic compounds in bamboo shoots confer multiple biological functions such as antimicrobial, antioxidation, anti-aging, and anti-fatigue (Proestos *et al*., 2013). Both cassava and bamboo shoots (BS) contain antinutrients that can render the food toxic and unpalatable. Current studies focus on utilizing underutilised food crops to enrich nutrient-deficient foods. The move is because there has been a reduction in food diversity, thus serious concerns about how effectively major crops can contribute to malnutrition, food security, ecosystem conservation, poverty alleviation, and biodiversity maintenance single-handedly. The development of composite foods has improved and diversified food products, significantly contributing to human nutrition (Wanjala *et al*., 2020). It is, therefore, important to investigate how blending bamboo shoots, wheat, and cassava flours affect the desired quality of the bread.

1.2 Statement of the Problem

The underutilisation of nutrient-dense local food crops has greatly contributed to food insecurity and malnutrition. Low-income families rarely afford nutritious meals to meet their dietary requirements due to high living standards. Insufficient nutritional supply is attributed to over-reliance on staple foods such as wheat, rice, and maize while neglecting local, cheap, and nutritious food crops. Wheat production has declined in Kenya due to the high costs of production. Wheat is mostly used in bread making. However, refining reduces protein, minerals, and dietary fibre, affecting bread quality. Furthermore, wheat is naturally deficient in lysine, tryptophan, and threonine. On the other hand, cassava flour utilisation in bakery and confectionery products is insignificant and relatively new in contrast to its potential. Developing a food product of high nutritional value involves using plant or plant-based products rich in certain nutrients of interest. Bamboo shoots rich in proteins, dietary fibre, minerals, and phytochemicals remain seasonal, region-specific, non-standardized, minimal, and traditional, with little value addition. With the rising preference for healthy, natural, and organic foods and the popularity of bamboo, this study aims at producing a composite flour of wheat, cassava, and bamboo shoots to be used in bread baking.

1.3 General objective

To contribute to food and nutrition security by utilising bamboo shoots and cassava in baked products.

1.3.1 Specific objectives

i. To determine the nutritional composition and physical properties of bread baked from wheat-cassava-bamboo shoot composite flour.
ii. To determine the rheological properties of wheat-cassava-bamboo shoot composite flour
iii. To determine microbial quality of bread baked from wheat-cassava-bamboo shoot composite flour.
iv. To determine the sensory properties of bread baked from wheat-cassava-bamboo shoot composite flour

1.3.2 Hypotheses

i. There is no significant difference in nutritional composition and physical properties of bread produced from wheat-cassava-bamboo shoot composite flour.
ii. There is no significant difference in the rheological properties of wheat-cassava-bamboo shoot composite flour.
iii. There is no significant difference in the microbial quality of bread produced from wheat-cassava-bamboo shoot composite flour.
iv. There is no significant difference in sensory properties of bread produced from wheat-cassava-bamboo shoot composite flour.

1.4 Justification

Despite the high demand, Kenya produces only 40% of its national wheat requirement. The low production is due to climatic reasons hence the need to import the 60% deficit (Wambua, 2017). Importing wheat is expensive as Kenya loses 2 billion Kenya shillings annually (Ogeto *et al*., 2013). The shortage in wheat supply has led to the demand for alternative local crops like cassava, sorghum and millet in baking. In Kenya, Western region is the highest producer with an average of 8.6 t/ha and consumes 60% of the production Wambua , 2017). The functional and physicochemical performance of cassava flour is vital during baking; high peak viscosity, early gelatinization, the low tendency of retrogradation, and large paste breakdown compared to wheat flour (Eriksson *et al.*, 2014). Flour compositing allows for an improved supply of nutrients for human nutrition, the promotion of underutilised food crops, and the diversification of food products (Raihan & Saini, 2017). Bamboo, the world's fastest-growing plant, is found in the Kenyan highlands, where the indigenous species (*Y. alpina*) covers almost 150,000 Ha of protected public land. The specie has remained underutilised after BS felling was banned by the government in 1986. As a result, the Kenya Forest Research Institute (KEFRI) started a research program and developed strategies exploiting the potential of bamboo and its cultivation in Kenya (Karanja, 2017; Kigomo, 2007). Food crops like bamboo shoots rich in nutrients have recently been the centre of innovative studies attracting both scientists and medical professionals alike. Bamboo shoots have been successfully utilised in Asian countries as vegetable, medicine and value addition hence augmenting food and nutrient supply in Kenya. Wheat, cassava and bamboo shoots can be blended to provide foods that are nutritious and healthy.

CHAPTER TWO

LITERATURE REVIEW

2.1 Bread consumption

Bread is a staple food commonly consumed for breakfast. Its production and consumption vary depending on consumer wishes which is difficult to predict (Eglite & Kunkulberga, 2017). Urban populations highly prefer bread compared to rural ones due to its convenience. The main raw material for bread making is wheat cereal (Ohimain, 2014). Wheat is largely used in bread making. Bread is the oldest universally accepted and consumed as convenience food worldwide by all age groups and populations (rich/poor, urban/rural). Wheat is commonly used in bread making due to its functional protein gluten, which contributes to dough elasticity and extensibility (Wambua, 2017). This unique property makes wheat a preferred crop in the confectionery industry. Billions depend on wheat to meet their dietary requirements (Ohimain, 2014). However, bread, cakes, cookies, and biscuits made from wheat are expensive since a larger percentage is imported. In sub-Saharan Africa, wheat consumption has steadily increased and is projected to be at 1.28 million tonnes by 2030. Bread consumption has also increased beyond wheat production due to population increase, urbanization, changing food preferences, and rising incomes (Abdelghafor *et al.*, 2011). In Kenya, Nairobi city has the highest bread consumption rate at 75%, while the country only produces 40% of its national wheat requirement (Cornelsen *et al.*, 2016). Consequently, the remaining 60% wheat is imported but is costly as the government spends 5.85 billion shillings per year (Wambua, 2017). Importing wheat has strained the economies of importing countries, leading to loss of foreign exchange, trade imbalance, and local food displacement (Ohimain, 2014).

Some factors that influence low wheat production include; unpredictable weather due to climate change, high costs of production, pests and plant diseases, and low technology adaptation levels (Mariera, 2018). Bread prices continually rise due to high production costs, which may contribute to food insecurity. Therefore, conventional strategies such as using locally grown crops like cassava and sorghum have been applied through compositing flours to mitigate the problem of wheat shortage. Using composite flours of legumes, tubers, and cereals has influenced the trend in consuming the new products (Nwanekezi, 2013). As consumption trends continue to change over time, consumer requirements in terms of nutritional quality also change. Globally, research focuses on improving the bread's nutritional value, consumer acceptability, shelf life, and phytochemicals to suit its affordability. Studies have shown that wheat grains usually undergo refining processes that greatly reduce the content of almost all its nutrients (Oghbaei & Prakash, 2016). Refining removes the bran and germ, resulting in the loss of minerals, vitamins, dietary fibre, phytic acid, lignans, and phenolic compounds. There is also a need to enhance the nutritional quality of bread through value addition by using underutilised food crops such as bamboo shoots

2.2 Baking properties of wheat- cassava composite bread

Wheat bread is highly consumed in most African countries to supply daily caloric intake despite low wheat production. Developing countries have sought local food crops like cassava for partial or full substitution of wheat flour in the baking industry. Composite flours are defined as blends of flours from tubers (cassava, sweet potato, yam) or cereals (millet, maize, rice, buckwheat) or protein-rich flours (soybean, peanut) and can be with or without wheat flour (Ohimain, 2014). They are beneficial because inherent deficiencies of essential amino acids (lysine, threonine, tryptophan) in wheat flour are acquired from other sources (Olapade & Adeyemo, 2014). Recent research has been based on cassava flour incorporation into the wheat-based dough for bread making (Chisenga *et al.*, 2019). Quality parameters such as cassava flour quality and its leavening ability are important in the wheat-cassava composite dough. However, more research is yet to be done on physical parameters like water absorption capacity, functional properties, bulk density, stickiness, and swelling power to pasting (Eriksson *et al.*, 2014).

Most countries commercializing cassava have sought a particular percentage of cassava flour inclusion into wheat flour in baking applications. According to Aristizábal *et al*. (2017), wheat flour can be substituted by 5-10 % cassava flour in bread making without significantly affecting the quality or processing of bread. On the other hand, other researchers investigated the inclusion of 10–30% cassava flour on the baking properties of composite wheat–cassava bread. The researchers reported variations in bread quality depending on the percentage of flour included and cassava variety (Eriksson *et al*., 2014). The specific bread volume, springiness, and difficulty in chewing reduced while hardness and density increased with increased proportions of cassava flour. The conclusion was that there was no significant difference between bread from composite flour substituted with cassava flour at 10% and 20% in terms of springiness, taste, and aroma and the control. The substitution levels of up to 10-20% were thus acceptable, according to the study.

However, cassava substitution usually affects colour, indicating that caramelization does not reduce as cassava flour levels increase. Similarly, the texture is negatively affected as insubstantial amylase enzyme activity on cassava starch dilutes wheat gluten functionality

(Shittu *et al.*, 2007). Also, texture variations in bread are greatly influenced by granule composition, physicochemical properties, and morphology for wheat and cassava. Various studies on the application of composite flour in the baking of bread have been extensively conducted to determine the quality of bread making as affected by the level of wheat flour substitution and wheat biological origin (Chisenga *et al.*, 2019; Renzetti *et al.*, 2023).

2.3 Cassava utilization

Cassava is a perennial woody shrub with edible roots which grows in tropical and subtropical areas. It is primarily produced for its roots, which provide a cheap carbohydrate source. It is an important energy source for most underdeveloped and developing countries. Cassava starch is also highly digestible, with no signs of significant α-1-2 and α-1-3 bonds proven through its hydrolysis to glucose by enzyme α-amylase (Abass *et al*., 2018). It grows well under marginal conditions and provides nutrients, especially where other crops fail. It is commonly grown in intercrops with maize, beans, and bananas. The global cassava production is about 225 million, consumed by over 200 million people as a staple crop (Obiero *et al*., 2007). In Asia, cassava production is mostly driven by the demand from starch industries and animal feed production (Bull *et al*., 2011; Howeler *et al.*, 2013; Parmar *et al*., 2017). Brazil and Thailand, on the other hand, produce 85% and 95%, respectively, where most production goes to processors (Onubuogu *et al*., 2014). In SSA, 60% of the population depends on cassava as their staple food crop. Nigeria has remained the leading producer of cassava globally since the 1980s, producing 45 million metric tonnes annually. Nigeria's cassava processing industry was mainly small, medium-sized, micro, or cottage enterprises in cassava flour, *gari*, starch, *fufu*, and cassava chips processing, limited to traditional technologies (Dada *et al*., 2010).

According to Dada (2014), Nigeria was yet to explore more than 40 million cassava demand for other industries like pharmaceutical, bakery, pulp, paper, and confectionery. Later, Cassava Transformation Agenda (CTA), an initiative in Nigeria, supported the promotion of High Quality Cassava Flour (HQCF) in the baking and confectionary industries to ensure industrial and public acceptance (Dada, 2016). As a result, a policy was formulated to promote cassava flour substitution for wheat flour at 20% for bread baking and confectionery products. For other products like cookies, biscuits, queen cakes, and sausage rolls, cassava was used at a 100% level (Dada, 2016). The move led to additional market opportunities for smallholder farmers and producing good quality bread. The initiative (CTA) created awareness about the multiple value-added products from cassava; composite (cassava-wheat) baking flour, chips, glucose syrup, flour starch, and ethanol (Shittu *et al*., 2007).

In Tanzania, cassava is the second most produced after maize hence ranking Tanzania seventh in Africa as a cassava producer. It produces 4,755,160 tonnes of cassava annually and is solely grown by low-income smallholder farmers (Reincke *et al*., 2018). There is a positive impact of cassava production on the food security status owing to the importance of cassava cultivation in Tanzania. Out of the cassava produced, one-third is marketed, while the remaining chunk is consumed by farmers growing the tubers; this is attributed to the perishability of the roots.

In Kenya, cassava consumption is limited to *ugali*, porridge, roasted, and boiled forms (Flibert *et al*., 2016). It is mostly grown in Western, Coast, Eastern, and Central regions, where production is concentrated in Coastal and Western parts of the country. The western region has the highest production and consumption, with an average of 8.6 t/ha and 60% of its national production, respectively (Wambua, 2017). In Kenya, the Ministry of Agriculture, together with the Kenya Agriculture and Livestock Research Organization (KALRO), has strived to promote cassava as a food crop with the aim of commercialization through training on value addition in agronomic production aspects, harvesting, postharvest handling, and utilization. Despite the intense training of farmers, cassava production is still low in Kenya and has not progressed to a commercial crop (Mulu-Mutuku *et al*., 2013). Studies done in the producing region showed minimal cassava processing, which occurs manually using simple equipment like knives for making crisps (Githunguri *et al*., 2017). The major challenges were postharvest cassava losses due to a lack of processing technologies and marketing channels for cassava and cassava products. Postharvest losses can be avoided by processing the cassava tubers within 24 hours of harvesting. The losses experienced, among other factors, have influenced the adoption of agricultural technologies to improve cassava production (Uzochukwu *et al.*, 2021). Also, cassava contains antinutrients like toxic cyanogenic glycosides (linamarin and lotaustratin), cyanohydrins, free cyanide, phytates, and oxalates.

For this reason, cassava requires special processing procedures to reduce to acceptable levels making the product more safe for human consumption (Sampson, 2020). These processing techniques include drying, soaking, crushing, boiling, eliminating hydrocyanic acid (HCN), and reducing the moisture content, making it durable and stable. Commercializing cassava processing can spark economic growth by creating substantial new business opportunities, job creation, promoting cassava production, boosting farmers' income, and reducing wheat dependence. However, its low protein quality (methionine and cysteine) and cyanogenic glucoside content has made it an inferior crop (Sampson, 2020) . Therefore, populations solely dependent on cassava have inadequate intake of dietary protein, zinc, βcarotene, and iron (Obiero *et al.*, 2007). The Table 2.1 shows specification criteria for cassava quality to be used in industries.

Table 2.1 Major quality criteria of cassava flour set by industrial users

Quality criteria	Specification
pH	5.0- 8.0
Moisture content (%)	10-12
Ash (%)	<0.9
Colour	White
Odour	Not detectable
Taste	None or sweet
Sand or any other contaminants	Not present
Particle size	Same as for wheat
Cyanogenic potential (CNP)	National (Nigeria)limit 10ppm

Source**:** Abass *et al*. (1998)

2.4 Utilization of Bamboo Shoots

Bamboo, a rapidly growing fibrous plant, belongs to *Poaceae* and subfamily *Bambuseae*. It grows in temperate, tropical and subtropical regions covering Latin America, Asia, Africa, and the Caribbean (Chauhan *et al*., 2016; Wang *et al*., 2020). It is a tall, perennial, woody grass identified as the fastest growing plant in the world. Most communities have utilized bamboo as raw materials for medicine, construction, food, shelter, and pulp for the industry. It is used in furniture making, musical instruments, handicrafts, bows and arrows, poles, and even boats. Japanese apply bamboo leaves as livestock fodder, and giant pandas in China use them as food since they only survive on bamboo. Some communities use bamboo as ornamental plants to beautify gardens and homes. Bamboos have great potential in alleviating environmental conditions like soil erosion control, land rehabilitation, water conservation and carbon sequestration (Chongtham *et al*., 2011). Bamboo sector has significantly contributed to mitigation of climate change through reduction of ecosystem carbon and carbon storage (Lugt & King, 2019; King et al, 2021). In Kenya, the bamboo species most common is *Yushania alpina*. The unsustainable exploitation of bamboo forests and their conversion to agricultural land for other uses may result into extinction of indigenous Kenyan bamboo species. A study

in 2010 established that Kenya had 450,000 ha of bamboo forests in 1940 compared to 150,000 ha in 2010, an evident result of climate change (Kigomo, 2007; Ndirangu, 2017)
While it is popular for industrial applications, little is known about utilizing bamboo juvenile shoots as food.

Bamboo is currently gaining much attention as an alternative crop with health, domestic, nutritional, and economic uses and benefits (Wang *et al.*, 2020). They are mostly fermented, fresh, marinated, canned, boiled, or frozen. They are delicious, rich in nutrients, including proteins, dietary fibre, carbohydrates, and minerals, and low in fat and sugars. Bamboo shoots contain biochemical components like phytosterols, polyphenols, and nutraceuticals that have raised its popularity among scientists. However, the consumption pattern of bamboo shoots is minimal, traditional, non-standardized, region-specific, and seasonal, with little value addition (Chauhan *et al*., 2016). Globally, over 2 million tonnes of bamboo shoots are consumed yearly, with China (the largest consumer) producing about 1.3 million tonnes of BS (Chongtham *et al*., 2011).

On the other hand, BS is mostly consumed in Southeast Asia and as approved ingredient in local cuisines (Wang *et al*., 2020). Bamboo shoots have been successfully utilized in several ways: First, *Saccharomyces cerevisiae* has been isolated from *Bambusa vulgaris* through its morphology observation under microscope, fermentative capacity test and ability to tolerate high temperatures (Ma & Noroul, 2011). The aim was to establish the leavening potential of the isolate which was carried out through dough fermentation then baking at 180°C for 8 min. It was able to leaven the highest specific volume compared to commercial yeast (Ma & Noroul, 2011). Fermentation occurred within a short time as a result of initiation immediately after inoculation in dough producing more carbon dioxide raising the dough, thus giving bread better physico-chemical characteristics. This is because yeasts ferment sugars such as glucose, fructose, maltose and sucrose.

Secondly, studies carried out by Mustafa *et al*. (2016) explored application of BS powder as a cheaper source with high nutritional contour to produce best quality baked products. After proximate analyses of the products, the juvenile shoots were found to contain higher amounts of protein (19.32%) and fibre (24.44%) contents with the lowest amount of fats (1.46%). Also, physical attributes portrayed exceptional dough making qualities when mixed with wheat flour. Sensory assessment revealed that the cookies prepared with 6% bamboo shoots fortified flour and below were acceptable.

Thirdly, Santosh *et al*. (2018) found out that freeze dried bamboo shoot powder can be used in fortification of biscuits. This study led to the realization that fortification enriched the biscuits with dietary fibre, proteins, bioactive compounds and minerals. Fresh freeze-dried fortified biscuits were found to contain nutrients at maximum; amino acids, protein, carbohydrates, phenol, phytosterols, neutral acid detergent fibre (ADF) and detergent fibre (NDF) at 0.30 g/100 g, 1.27 g/100 g, 20.45 g/100 g, 0.22 g/100 g, 0.18 g/100 g, 5.16 g/100 g and 62.44 g/100 g, respectively. The fortified biscuits contained high amount of minerals including; K, Ca, Fe, P, Mn, S, Na, and Zn. These minerals are essential in managing hidden hunger among populations. Potassium is a heart-friendly mineral that helps to maintain steady heartbeat and normal blood pressure.

Finally, bamboo shoots (*Yushania alpina*) and Sorghum (*Sorghum bicolour L.*) have been employed in the optimization of dietary fibre and protein content in rice (*Oryza sativa*) flour (Wanjala *et al*., 2020). A high level of HCN content (117.81 mg/kg) was established in fresh bamboo shoots but after drying, the level reduced significantly to 2.313mg/kg. This accounted for 98.3% decrease. Increasing the levels of BSF flour in the blends also contributed to increased protein content, total minerals and dietary fibre. It was further established that the optimum blend contained bamboo shoots at 23% (50:27:23 for rice, sorghum and BS flour respectively). This composite flour contained 3.9% total minerals, 6.2% dietary fibre and 13.4% protein (Wanjala *et al*., 2020)**.** The high content of hydrogen cyanide is greatly reduced by processing procedures such as drying and thermal processing which reduce the level to safer magnitudes.

2.5 Nutritional and health benefits of bamboo shoots

The major nutrients in bamboo shoots are protein, dietary fibre, carbohydrates, minerals, and inorganic salts. Major minerals in the juvenile shoots include potassium, zinc, calcium, copper, iron, chromium, manganese and little amounts of selenium and phosphorus (Nirmala *et al.*, 2007). They are rich in niacin, thiamine, vitamin B_6, vitamin A, and vitamin E (Wang *et al.*, 2020). The fresh bamboo shoots are an excellent source of protein, containing an average of 2.65 g p/100g. The protein contains 17 amino acids, of which 9 are essential amino acids. The tyrosine content amounts to 57% - 67% of the total amino acid content. They have comparatively low-fat content 0.26% - 0.94% and total sugar content (average 2.5%) which varies in bamboo shoot species and maturity stage (Chongtham *et al*., 2011).

The polysaccharides present in BS are starch, cellulose, hemicelluloses and other minor complex polysaccharides like glycoproteins (Tanabe *et al*., 2017). The hemi-cellulosic polysaccharides are composed of arabinoxylan, glucomannan xyloglucan, β-D-glucan, and arabinogalactan. On the other hand, the major oligosaccharides have been identified as xyloglucan disaccharide sucrose, arabinoxylan trisaccharide and tetra saccharide (Wang *et al*., 2020).

The health benefits of the juvenile shoots are as a result of bioactive components present, mainly phytosterols, phenols and dietary fibres. They promote health and provide protection against human degenerative and chronic diseases. Phenolic compounds confer numerous biological effects including; anti-fatigue, antioxidation and antimicrobial activities. Their antimicrobial properties have been effective against *Fusarium oxysporum, Aspergillus niger, Candida albicans, Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, and Escherichia coli* (Nirmala *et al*., 2014). Dietary fibre and phytosterols have a positive impact on bowel movement, lipid profile, reduce total serum cholesterol and low-density lipoprotein cholesterol level. The insoluble dietary fibre accounts for 60–90% of the total carbohydrate (Felisberto *et al*., 2017; Karnjanapratum *et al*., 2019). The total dietary fibre on a dry mass basis varied between 19.3 g/100 g to 35.5 g/100 g (Satya *et al*., 2010). Major components of dietary fibre in bamboo shoots include hemicellulose, lignin, ADF, cellulose and NDF. A 10-day storage of fresh shoots leads to double increase in dietary fibre content though varying in different parts of bamboo shoots (Nirmala *et al.*, 2007). For instance, in *Yushania alpina* the lower and upper parts had indicated 30.7 g/100 g dry basis and 23.9 g/100 g dry basis respectively (Karanja, 2017). In contrast, *Dendrocalamus giganteus* was reported to contain 0.97 g/100 g wet basis on the basal part and 0.96 g/100 g wet basis at the top, thus were comparable (Singhal *et al*., 2013). Dietary fibre usually incorporated into dairy, bakery products and soups can stabilize high fat food and emulsions, modify textural properties, prevent syneresis and improve shelf life. In determining the taste and mouthfeel of bamboo shoots, the level of dietary fibre is important as high amounts from older shoots are of lower eating quality.

Santosh *et al*. (2018) analysed the bioactive compounds, mineral elements and dietary fibres both in fresh bamboo shoots and freeze-dried bamboo shoot powder before mixing freeze-dried bamboo with wheat flour for biscuits baking. Fresh shoots showed the highest amounts of all nutrients compared to freeze dried samples. Phenols and antioxidants (vitamin C and vitamin E) play vital roles in human health as they neutralize cell damage caused by free radicals in the body. On the other hand, phytosterols have cholesterol-lowering potential and reduce cancer, cardiovascular disease incidences, and other related chronic diseases.

The recommended adequate intake of dietary fibre is 25 g for adult females, children is 14–28 g and for adult males is 30 g. Consequently, the Dietary Reference Intake (DRI) for protein is 0.8 g per kilogram of one's body weight which basically amounts to 46 g per day for an average inactive woman and 56 g per day for an average sedentary (Volpi *et al.*, 2013). Wheat, cassava and BS have varying amounts of nutrients as in Table 2.2

Table 2.2 Comparison of the nutrient composition in 100 g on dry basis for *Yushania alpina,* cassava and wheat flours

Food group	*Yushania alpina* (g/100g)	Cassava (g/100g)	Wheat (g/100g)
Proteins	31.3-33.4g	0.3 - 3.5	13-16.7g
Carbohydrates	17.3- 23.6g	38.6g	71.2g
Dietary fibre	12.17-30.7g	1.2-4.6g	8.9-11.4g
Ash	13.67g	1.3-1.28g	1.27-2.01g
Fats	2g	0.03 - 0.8g	2.5-3.7g

(Edhirej *et al.*, 2017; Karanja *et al.*, 2017; USDA, 2020)

2.6 Anti-nutrients in bamboo shoots and cassava

Anti-nutrients are chemical compounds found in plants. They can cause toxicity, hinder absorption of essential nutrients in the body or render the food unpalatable when consumed. Tannins, cyanogenic glycosides, phytates, oxalates, and silica are found in bamboo shoots, while cyanogenic glucosides (linamarin and lotaustratin), cyanohydrins, phytates, free cyanide, and oxalates occur in cassava. Cyanogenic glycosides like hydrogen cyanide can be found in fresh shoots of bamboo and occur as taxiphyllin. Taxiphyllin is highly toxic to humans with about 50-60 mg as the lethal dosage. It also acts as enzyme inhibitor when produced in the body (Holstege *et al*., 2010). This toxin is a p-hydroxylated mandelo-nitrile triglochinin that decomposes rapidly in boiling water (Ferreira *et al*., 1995). Taxiphyllin is hydrolysed by β-glucosidase (hydrolytic enzyme) to sugar and a cyanohydrin compound that quickly decomposes to a ketone or aldehyde and hydrogen cyanide. The permissible limit of cyanogen content in food is 500 mg/kg (Moller & Seigler, 1999). Tannins occur both as hydrolysable and non-hydrolysable hence condensed tannins. They precipitate proteins by inhibiting digestive enzymes and exhibiting anti-amylase and anti-trypsin properties in aqueous media. This renders the proteins absent thus considered anti-nutritive to the body (Soetan & Oyewole, 2009). Phytic acid is a carrier of phosphorus and occurs as inositol hexa-phosphates in plants. It is complexed with some dietary nutrients like copper, calcium, zinc, magnesium, iron and proteins thus making the minerals bio-unavailable in the body resulting into health problems (Jemal *et al.,* 2011).Various technologies like enzyme hydrolysis, boiling, drying and fermentation have been used to reduce these antinutrients in bamboo shoots. Taxiphyllin is easily hydrolysed by β-glucosidase enzymes yielding glucose and 4-hydroxy-(R)-mandelonitrile. This is then broken down by hydroxynitrile lyase enzymes to hydrogen cyanide and benzaldehyde (Gleadow & Møller, 2014). Similarly, boiling helps remove the bitterness in the shoots as it ruptures the cell walls releasing anti-nutrients as part of the cell contents. Boiling of shoots in different concentrations of NaCl and time intervals helps remove cyanide with limited loss of nutrients (Pandey & Ojha, 2014). Drying reduces water activity which in turn reduces volatile toxins when stored for a long time. Fermentation, a method of food preservation improves the nutritional quality and sensory attributes of a food. This occurs through biosynthesis of essential amino acids, vitamins and anti-nutrients degradation (Karanja *et al.*, 2015). *Lactobacillus plantarum* in fermentation of bamboo shoots possesses the ability to degrade phytic acid hence improving the safety of the shoots (Nongdam, 2015). Different fermentation methods have varying effects on nutrients.

2.7 Acceptability of wheat-cassava bread

Wheat flour in which cassava flour replacement is up to 30% and 20% level of substitutions produce acceptable bread with insignificant variation, when compared to bread made with 100% wheat flour **(**Eddy *et al*., 2007). However, inclusion of up to 30% cassava flour shows low mean scores to all the attributes except for gumminess. According to Jensen *et al*. 2015, there was a tendency for bread baked with 10% and 20% cassava composite flour to have a higher rating than the control especially in aroma, colour, flavour, general and acceptability which leads to consumers' preference to buy. Study has shown that 10% and 20% cassava flour in wheat-cassava composite flour bread recipes could be a viable alternative to achieve food security, desired economy and health (Sampson, 2020). As much as 10% cassava flour substitution is recommended for acceptable sensory characteristics, its index to volume scores is relatively higher in breads made from the blends. Increased gumminess, reduced the protein and fat content in composite bread which is affected by increased cassava levels during substitution **(**Eddy *et al*., 2007).

2.8 Shelf life of wheat bread

Bread is one of the food products with a short shelf of between 3-7 days at room temperature. The shelf-life and quality of bread highly depend on the ingredients applied in baking (Onyango, 2016). The crust forms a primary protective barrier that prevents degradation by microorganisms and moisture loss (Ahmad *et al*., 2016). Deterioration of bread begins immediately after baking due to physical and chemical changes that occur. Starch retrogradation, migration and redistribution of water and gluten transformation, are the major causes of staling in bread (Wanjuu *et al*., 2018). This affects bread texture as it intensifies the opacity, hardness and crumbliness thus attracting micro-organisms like moulds. Mould growth mostly occur in bakery products with medium and high-water content (Ijah *et al*., 2014). Some of the factors affecting mould growth include; product type, season and product preparation conditions accounting for 1-5% loss in bakery products globally (Alpers *et al*., 2021). Mouldiness and ropiness are the most common kinds of bread spoilage by microbes. Mouldiness is caused by aspergillus, fusarium, claslosporium, penicillium and rhizopus species (Vlášek *et al*., 2013). Ropiness is caused by *Bacillus subtilis* and *Bacillus licheniformis*. Wheat flour substitution is considered to influence the nutritional, textural, organoleptic characteristics and shelf-stability of the bread (Wanjuu *et al*., 2018). According to Saranraj and Geetha (2012), foodborne diseases arise from unhygienic and contaminated baked products; thus, analysis is important as these may adversely interfere with consumers health.

Research Gap

Cassava processing in Kenya is still carried out manually using crude-plane like equipment and knives for crisps processing. Lack of improved processing techniques for cassava value added products and marketing channels are a major constraint to cassava producers in Kenya. On the other hand, there is inadequate information regarding utilisation of bamboo shoots in supplementation of nutrient deficient food in Kenya. Most researches have been focusing on soybean, chickpeas, amaranth and buckwheat for enrichment of wheat bread with the aim of improving its nutritive value. Despite bamboo shoot being recognized in Asian countries as a common delicacy, most African countries are missing out on its nutritional and health benefits due to lack of awareness.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area and materials

The edible shoots of indigenous *Yushania alpina* were sourced from Mt. Elgon National Reserve, Kenya. The young shoots were harvested at 4 - 6 weeks after the onset of April-May 2021 rainfall. Cassava (*selele* variety) were obtained from Kenya Agriculture and Livestock Research Organization (KALRO), Njoro. Wheat flour, sugar, salt, baker's yeast and margarine were sourced from Naivas Supermarket in Nakuru town, Nakuru County, Kenya. The rheological properties were analysed at Unga Ltd, Nairobi while the physical properties of bread were analysed in the Cereal Chemistry Laboratory at KALRO. The proximate composition was analysed at the Department of Animal Science Laboratory while microbial analyses and sensory evaluation were conducted at the Department of Dairy and Food Science and Technology, Egerton University.

3.2 Preparation of flours

3.2.1 Cassava flour

Matured cassava roots were prepared between 10-24 h postharvest using the method described by Aristizábal *et al*. (2017) with some modifications. The cassava tubers were peeled using kitchen knife, washed in clean running water, then chipped using a motorized cassava grater to reduce their size and increase the area of heat transfer during the drying process. The chipped cassava samples were then sun dried to achieve 10-12% moisture content and milled using a hammer mill fitted with a sieve with pore size of 250 µm screen. Sieving removes the remnant fibre giving fine flour with uniform particle size. The flour was stored in sealed polythene pouches at 10°C for further analyses.

3.2.2 Bamboo shoot flour

Bamboo shoot flour was prepared according to Wanjala *et al*. (2020). The 2-3 layers of husks were removed and soft edible portions washed in clean running water. The soft portions were cut into small pieces and partially sun dried then fully oven dried at 60°C for 72 h to a moisture content of ≈10%. The dried shoots were milled using a hammer mill fitted with a sieve with pore size <800 µm and stored in sealed polyethylene pouches at 10°C awaiting further analyses.

3.2.3 Composite flours

Composite flours were prepared from wheat, cassava and BS flours using different ratios of wheat, cassava and BS flours. Bamboo shoot flour was composited with wheat: cassava (80:20 respectively) at four levels; 2.5%, 5%,7.5%,10%. This resulted into five groups of composite flours; 80%:20%:0% (control), 78%:19.5%:2.5%, 76%:19%:5%, 74%:18.5%:7.5%, 72%:18%:10% used in the bread baking and other analyses.

3.3 Preparation of wheat: cassava: bamboo shoot composite bread

Loaves of bread (400 g) were baked from each composite of batch according to Agunbiade *et al*. (2017) with some modifications as in Figure 3.1. Each formulated flour was

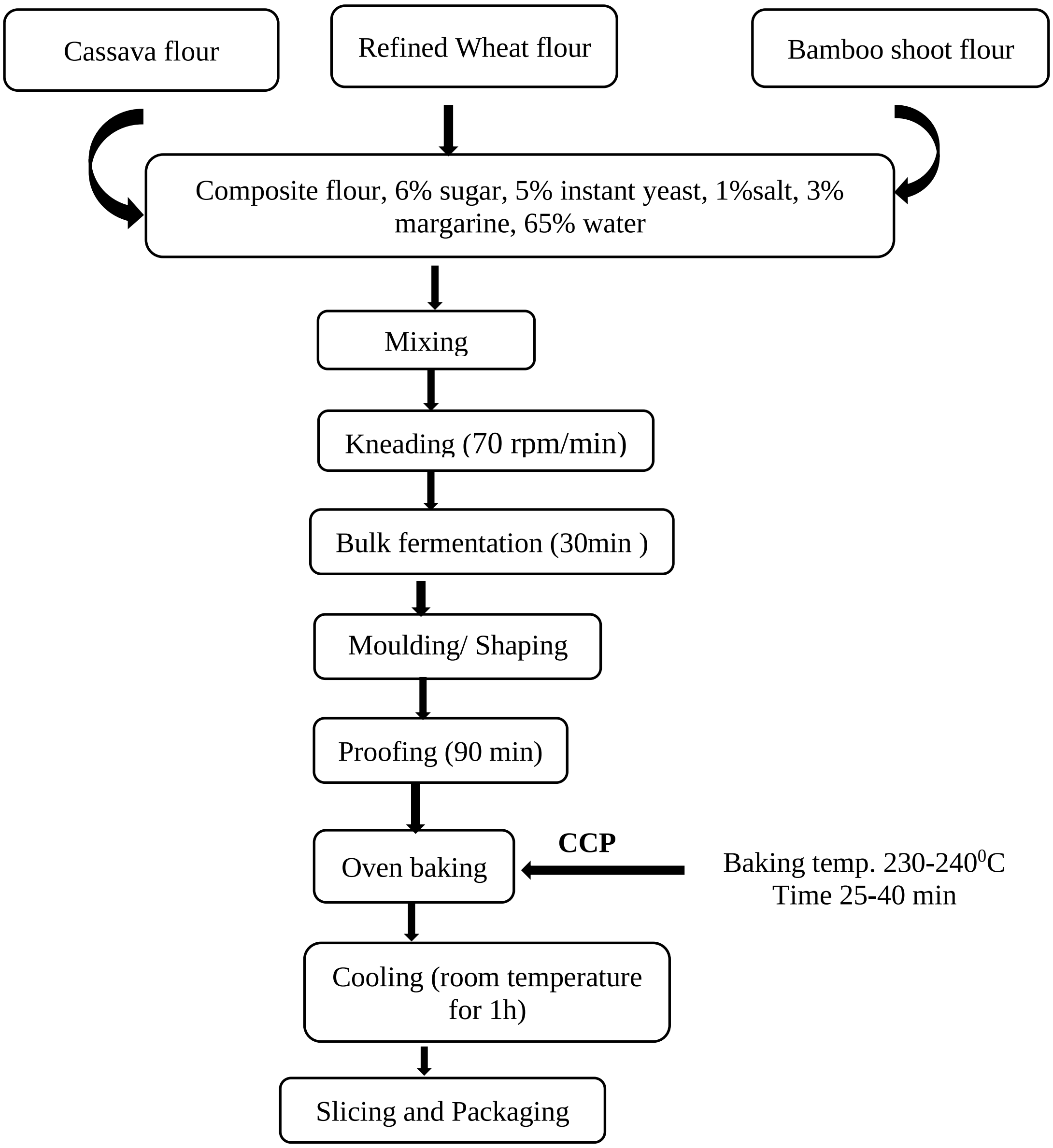


Figure 3. 1 Flow chart for the production of bamboo shoot enriched bread

discharged into a mixing bowl containing 1% salt, 3% margarine, 5% instant yeast and 6% sugar. The dry ingredients were thoroughly mixed then 65% water added and mixed into dough. The dough was then removed and kneaded at a speed of 70 rpm/min for about 2-7 min to achieve dough consistency (the more the BS the longer the kneading time). The dough was rolled into a ball-like structure transferred to a bowl greased with margarine and transferred into fermentation chamber for 30 min (first rise). The dough was subjected to punching then moulded by passing it through the moulding machine the put in a coded greased baking pan and allowed to proof (90 min) until it obtained 2.0-2.5 cm above the pan. Baking was done in a preheated oven at 230-240˚C for 25-40 min. The loaves were left to cool for 1h, sliced and packed in Ziploc bags after cooling awaiting sensory evaluation.

NB: Wheat and cassava were composited in the ratios 80:20 (Eriksson *et al.*, 2014). Pre- trial experiments using BS verified the workability of up to 10% BS in bread making with the control aforementioned ; thus, was incorporated

3.4 Analyses

3.4.1 Proximate analysis of the composite bread

Determination of Total Solids Content

The air oven method according to AOAC (2012), Method 967.19 was used. About 2 g ground sample was weighed accurately then placed on dry aluminium dishes and oven dried at 103˚C for 3 h. The air-dried sample was cooled in the desiccator before weighing. The total solids were calculated as follows:

$$\text{Total solids }(\%) = \frac{weight\ of\ dry\ sample}{weight\ wet\ sample} \times 100 \text{……………….. Equation 3.1}$$

Determination of Crude Protein Content

Crude protein was determined by Kjeldahl method according to AOAC (2012), Method 920.87. About 1 g bread sample was weighed into a test tube and digested using 10 mL concentrated H_2SO_4 in the presence of selenium catalyst until the colour change was observed (blue). The digest later underwent steam distillation using 40% NaOH. Ammonia was released then trapped in a solution of boric acid. The distillate was collected and about 60 mL titrated with 0.02 M HCl in the presence of methylene blue indicator until the colour change was observed (orange). The protein content was determined by multiplying the percent nitrogen content by 6.25.

$$\text{Nitrogen (\%)} = M\text{HCL} \times \frac{Corrected\ Acid\ volume}{Weight\ of\ sample} \times \frac{14gM}{Mol} \times 100$$ ....Equation 3.2

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$ .... Equation 3.3

where: Corrected acid volume = (volume of acid sample –volume of acid blank), M HCl = Molarity of HCl, 14 g= atomic weight of nitrogen, 6.25 = conversion factor equivalent to 0.16 g nitrogen per gram of protein

Determination of Crude Fat Content

The crude fat was determined by Soxhlet extraction according to AOAC (2012), Method 920.86. Approximately 5 g test sample was weighed into an extraction thimble then covered with cotton wool. Petroleum ether was added into a clean dried boiling flask. The thimble was placed into the Soxhlet extractor and fat extracted into a tared flask for 6 h using petroleum ether at a rate of 2-3 drops per second by heating the boiling flask in a water bath. The solvent (petroleum ether) was evaporated in a rotary evaporator and the residue dried in an air oven at 105˚C for 30 min, cooled in a desiccator then weighed and recorded.

$$\%\, CF = \frac{(\text{Weight of sample before extraction} - Weight\ of\ sample\ after\ extration\,)}{\text{Weight of sample before extraction}} \times 100$$ ....Equation 3.4

Determination Ash Content

The ash content was determined using AOAC (2012), Method 923.03. Exactly 5 g sample was accurately weighed and placed into a dry crucible. The sample was charred with flame to decompose all the organic components signified by an end to smoke emission. The sample was incinerated in a muffle furnace at 550°C for 6 h. The sample was cooled to room temperature in a desiccator then weighed.

$$\%\, Crude\ ash = \frac{Weight\ of\ ash}{original\ weight\ of\ sample} \times 100$$ .... Equation 3.5

Determination of Crude Fibre Content

The fibre content was determined using AOAC (2012), Method 987.10. Exactly 2 g sample was weighed into a conical flask. About 100 mL boiling distilled water and 1.25% H_2SO_4 solution were added respectively. The volume of the mixture was made up to 200 mL with boiling distilled water and maintained at this volume while boiling for 30 min on a hot plate. The mixture was filtered using a funnel lightly packed with glass wool and the residue washed 3 times in boiling distilled water to remove the acid remains. Approximately 100 mL distilled water and 25 mL 1.25% NaOH was added to the residue and the volume made up to 200 mL using boiling distilled water and this volume maintained while boiling on a hot plate for 30 min. The mixture was filtered using glass wool and washed three times in boiling water. The residue was washed further three times with small amounts of ethanol. Afterwards, the residue and glass wool were quantitatively transferred to a porcelain dish and dried in an air oven at 105°C for 2 h and weight recorded as W_1. It was put in the muffle furnace at 600°C for 2 h to undergo thermal decomposition. The residue was cooled in a desiccator and final weight recorded as W_2. The procedure was repeated for other composite groups of loaves, each in triplicate.

$$\%\ Crude\ fibre = \frac{(W_1 - W_2)}{W} \times 100 \text{..............................} \quad \text{Equation 3.6}$$

Determination of Total Carbohydrates Content

The total carbohydrate content was obtained by finding the sum of % moisture, % crude fat, % crude protein, % ash content and % crude fibre, then subtracting from 100% (Ani & Abel, 2018).

Determination of Energy Value and Energy-to-Protein Ratio

The energy value/content of the samples was obtained by multiplying the values obtained for crude protein, total carbohydrates, crude fat and dietary fibre by 4.00, 4.00, 9.00 and 2 Kcal/g, respectively, then values added (FAO/GoK, 2018). Energy-to-protein was determined by dividing the energy value of the sample by its crude protein content.

3.4.2 *Determination of physical properties of wheat-cassava composite bread*

Loaf volume, weight and specific volume

The loaf volumes were determined using rapeseed displacement method AACC (2000), Method 10-05.1. The weights of loaf samples were determined before cooling using a digital balance (0.01 g accuracy). The specific volumes of loaves were then calculated as;

$$\text{Specific Volume(cm3/g)} = \frac{\text{Volume}}{Weight} \text{....................} \quad \text{Equation 3.7}$$

Crumb colour

Various colour parameters L* (Lightness), a* (Redness to Greenness), b* (Yellowness to Blueness) of loaf samples were determined using Hunter Colour Meter as per the method described by Siddiq *et al*. (2009). The results were expressed in the CIELAB colour space. Browness Index (BI) was then calculated according to (Maskan, 2001)

$$BI = \frac{\{100(x-0.31)\}}{0.17} \text{.......... Equation 3.8}$$

$$x = \frac{(a+1.75L)}{5.645*L+a-3.012b} \text{.......... Equation 3.9}$$

where a* is redness, b* is yellowness, and L* is lightness.

3.4.3 Determination of Composite Dough Rheological Properties

The rheological properties of the composite flours were determined using Mixolab 2 (Chopin, Tripetteet France) as described by Sharma *et al*. (2017). Samples were hydrated to optimum level of composite flours to achieve optimum consistency of the dough. The water absorption (%), dough development time (min); dough stability (min), Maximum consistency and softening time were Mixolab parameters analysed.

Normal Falling Number

The Falling Number (FN) of formulated composite flours were determined using a falling number machine (Perten Instruments, FN 100, Springfield) using AACC (2010), method 56–81.03. Accurately weighed 7.0 g sample (14% moisture) was blended with 25 mL distilled water in a FN tube. The mixture was vigorously shaken using a shaker for 3 s. A viscometer-stirrer was placed into the tube then transferred into the FN machine. The tube was kept in warm water bath for 5s and stirred for 55 s. The machine recorded time taken by the stirrer to fall from the top of the tube to the bottom. The machine then recorded the time taken for the stirrer to fall from the top to the bottom of the tube. The FN reading was recorded as the sum of 5 s spent in the warm water, 55 s of stirring, and the time taken by the stirrer to fall.

3.5 Microbial analysis of wheat – cassava – bamboo shoot composite bread

Samples were ground and 10 g weighed from each sample. The samples were blended with peptone water and thoroughly shaken to form a suspension. Ten-fold serial dilutions were made up to 10^{-3} dilution factor. Plate count agar (PCA) was employed for Total viable bacterial counts (TVC), MacConkey Agar for Total Coliforms Count (TCC) and Potato Dextrose Agar (PDA) for fungal (yeast and moulds) counts. Pour plate technique culture was used for every sample (Jay *et al*., 2005). The media and samples were prepared in triplicates by weighing required amounts (as indicated in each label) then transferred into glass bottles and sterilised in an autoclave at 1210˚C and 1.5 pressure. The media bottles were removed from the autoclave and allowed to cool to 48°C to prevent the media from killing the microorganisms and at the same time avoid media solidification.

3.5.1 Pour plate procedure

The diluents of 10^{-1}, 10^{-2}, 10^{-3}, for each sample were used for pour plating. For every diluent, 1 mL was transferred into the labelled sterilized petri dishes for the different samples and tests using a micropipette. The glass bottle bearing the media was carefully opened and the sterilized using a Bunsen burner before transferring the media to the petri dishes with the sample to ensure aseptic conditions are maintained. Each petri dish was swirled gently to mix the media agar with the sample. The media was allowed to solidify and the plates incubated at 37∘C for 24–48 h for TCC and TVC while yeast and moulds at room temperature for 3–5 days (Jay *et al*., 2005).

3.5.2 Isolation and enumeration of microorganisms

After incubation the petri dishes were removed from the oven and the colonies were counted and recorded then average expressed as colony forming units per gram (cfu/g). For coliforms, the distinct colonies were sub-cultured in Eosin Methylene Blue Agar (confirmatory test), a selective media to obtain pure cultures for identification of the presence of *Escherichia coli* (Das *et al*., 2020).

3.6 Sensory Evaluation of wheat-cassava-bamboo shoot composite bread

3.6.1 Recruitment and screening of the panellists

Students and staff members at the Department of Dairy and Food Science and Technology, Egerton University who were voluntarily willing to consume bamboo shoot bread, had experience of descriptive sensory analysis and had no allergies were invited through emails and phone calls to take part in sensory evaluation. Out of 28 people who responded, 15 people attended an introductory session and were subjected to screening and signed consent form to enable their participation. Induction was conducted with the individuals to familiarise themselves with the food ingredients used in bread formulation. Standard screening was used in the screening procedure to test their capacity to distinguish various sensory tastes; sour, salty, bitter, umami, sweet (Tamayo & Tamayo, 2020). Also, the lexicon identification that outline the taste, flavour, aroma and aftertaste of presented wheat-cassava-bamboo shoot loaves of bread was included. The panel recruited consisted of eight females and seven males between the ages of 21-37 years.

3.6.2 Training of the panellists

The selected panellists were trained for 5 days, in a two-hour session each day as per the generic descriptive method (Einstein, 1991). During the training sessions, the bread was described over and over to guarantee uniformity in understanding among the panellists. Scale anchors and lexicons for the descriptors were developed by engaging panellists, well defined and settled on.

3.6.3 Descriptive sensory evaluation of wheat-cassava-bamboo shoot composite bread.

The loaves were sliced (2×3×5 cm) after cooling using a bread knife and served in disposable plates. The descriptive sensory evaluation of the composite loaves was conducted in a sensory evaluation room at the Department of Dairy and Food Science and Technology, Egerton University in individual booths. For every session of tasting, four bread samples representing the four types of bamboo shoot composited flours were freshly baked and used. Composite bread was baked using 400 g of the respective flours while keeping other baking conditions constant. Tap water was also provided in disposable tumblers for rinsing the mouth in between tasting of the samples. The samples were coded to allow for randomisation when samples are presented to panellists. The descriptive profiling of the 5 types of bread by the panel yielded 16 sensory descriptors grouped into appearance, aroma, texture, flavour and taste to describe bread as presented in Table 3.1. The samples were evaluated through sniffing, chewing, and swallowing. Responses were fed immediately in JMP software version 16.1 (SAS Institute, Inc.)

Table 3. 1 Lexicons for descriptive sensory evaluation developed by sensory panel to evaluate composite bread

Attribute	Definition	Reference	Rating scale
Appearance			
Crust Colour	The colour of the sample crust	7- colour of crust of baked wheat bread	1- White 7- Brown
Crumb Colour	The colour of the sample crumb	7- colour of crumb of baked wheat bread	1- White 7- Brown
Density	Compactness of the air spaces/ crumb cell number	7- air spaces in the bread crumb	1- Small number 7- Large number
Aroma			
Baked bread aroma	Intensity of aroma typical of cereals mixed with boiling water.	7- baked wheat products aroma i.e., bread.	1- None 7- Intense
Additional aroma	Intensity of aromatic characteristics as a result of bamboo shoots incorporation	7- aroma of baked bamboo shoot flour	1- None 7- Intense
Odour intensity	Associated with rancid smell or staleness	7- smell of rancidity of baked bread	1- Less 7- Intense
Texture			
Hardness	Associated force required to first bite throughout the sample with the molars	7- toughness during chewing	1- Soft 7- Hard
Grittiness:	Amount of small, hard particles between the teeth after swallowing	7- coarseness or presence of granules in the bread	1- None 7- High
Stickiness	Degree to which residues stick to the teeth during mastication	7- residues in the mouth during chewing	1- None 7- High
Chewiness	Number of chews required before swallowing the piece of bread.	7- number of times of chewing the sample	1- Small number 7- Large number

Table 3.1: Continued

Cohesiveness	Degree to which the chewed sample holds together	7- compactness of the sample during and after chewing	1- Crumble 7- Compact
Taste			
Aftertaste	The intensity associated with bamboo shoot flavour perceived in the mouth after swallowing	7-Aftertaste of bamboo shoot baked in bread	1- Less 7- Intense
Flavour			
Salty	The intensity of flavour associated with iodized salt.	7- flavour of salt used as an ingredient in bread baking	1- Less 7- Intense
Sweetness	The intensity of flavour associated with sugar perceived from baked products.	7- flavour of sugar as an ingredient in bread	1- Less 7- Intense

3.6.4 Determination of consumer acceptability of wheat-cassava-bamboo shoot composite bread

In-house testing was conducted at the Department of Dairy and Food Science and Technology, Egerton University. The loaves of bread were cut into 2×3×5 cm slices using a kitchen knife then coded differently. The samples were assessed by 50 semi-trained panellists (27 females and 23 males) between 11-12 noon and 3-4pm; where texture, colour (crust and crumb), aroma, taste and overall acceptability were analysed. A five-point hedonic scale was employed where; 1= dislike extremely, 2 = dislike, 3 = neither like or dislike, 4 = like and 5 = like extremely to rate different bread qualities (Lawless & Heymann, 2013). Panellists were given basic instructions and time to score the samples against attributes provided in score sheets in Appendix 3. The evaluations were conducted under room temperature and white light.

3.7 Experimental Design

The experiment employed a Completely Randomized Design (CRD) where major treatment was bamboo shoots. Composite flours obtained for analysis were five (n = 5) containing different portion of BS at five levels. Wheat and cassava were composited in the ratios 80:20 as control (Eriksson *et al*., 2014).

Statistical model;

$$\boldsymbol{Y_{ij} = \mu + \tau_i + \varepsilon_{ij}} \text{... Equation 10}$$

where, $\boldsymbol{Y_{ij}}$ is the response variable: $\boldsymbol{\mu}$ is the overall mean; $\boldsymbol{\tau_i}$ is the effect of the $\boldsymbol{i}^{\text{th}}$ treatment and $\boldsymbol{\varepsilon_{ij}}$is the random error term associated with the $\boldsymbol{Y_{ij}}$**.** The response variables included; rheological and physical properties, proximate composition, microbial count and consumer acceptability (Output observed, Y). Fifteen different samples of composite flour were prepared from wheat, cassava and bamboo shoot flours as follows; wheat: cassava: bamboo shoots, 80%:20%:0%, 78%:19.5%:2.5%, 76%: 19%:5%, 74%:18.5%:7.5%, 72%:18%:10% with 80%:20%:0% serving as control. The composite flours were packed in dry polythene paper bags for analysis. The experiments were executed in three replications.

CRD was preferred as it is best suited for experiments with small number of treatments. This study had 5 treatments each replicated 3 times.

3.8 Statistical analyses

Data obtained from rheological properties of flours and physical properties, proximate analysis, microbial count and sensory evaluation of wheat-cassava-bamboo shoot composite bread was analysed by SAS Version 9.4 for Analysis of Variance (ANOVA) using General Linear Model (GLM) procedure. Mean separation was done using Tukey's Studentized Range Test at $p \leq 0.05$. Principal component analysis (PCA) was conducted on the descriptive sensory characteristics using PROC FACTOR data analysis procedure to test the correlation that exist between the bread types and attributes scored by the panellists (Lawless& Heymann, 2013).

CHAPTER FOUR

RESULTS AND DISCUSSION

To determine the effect of compositing bamboo shoot flour with wheat-cassava flour on the quality aspects of resulting composite flour and bread, various parameters of the products were analysed. These included rheological properties of composite flour and physical, nutritional, microbial and sensory characteristics of composite bread. As such, several studies have shown that bamboo shoot incorporation in other wheat-based products increases their protein, dietary fibre, mineral and health promoting bioactive compounds such as phenols and phytosterols (Karanja, 2017; Santosh *et al*., 2016).

4.1 Nutritional Composition of Ingredients (wheat, cassava, bamboo shoots)

The nutritional variables for wheat, cassava and BS are shown in Table 4.1. The dry matter content of BS was the highest at 95.59% compared to wheat and cassava that recorded 88.57% and 88.93%, respectively. However, bamboo shoots and wheat had no significant ($p > 0.05$) difference in fat content compared to cassava.

Table 4. 1 Nutritional Composition of Wheat, Cassava and BS flours

Ingredient	Dry Matter (%)	Ash (%)	Crude Fat (%)	Crude fibre (%)	Crude Protein (%)	Total CHOs (%)	EV Kcal/100g	ER (Kcal/g of Protein)
Bamboo	95.6±0.58^{a}	16.6±0.25^{a}	2.22±0.17^{a}	19.7±1.26^{a}	29.4±0.36^{a}	27.6±0.48^{c}	287±0.48^{b}	9.78±0.10^{b}
Cassava	88.9±1.40^{b}	2 .71±0.12^{b}	0.39±0.10^{b}	0.19±0.04^{b}	4.60±0.28^{c}	81.0±1.49^{a}	346±5.25^{a}	76.0±5.84^{a}
Wheat	88.6±1.33^{b}	1.06±0.08^{c}	1.37±0.20^{a}	0.18^{b}±0.03^{b}	15.3±0.84^{b}	70.7±1.19^{b}	356±5.82^{a}	23.4±1.32^{b}

CHOs = Carbohydrates; EV = Energy Value; ER = Energy to protein ratio; values are mean±stdev. Values along the column followed by different superscript letter notations are significantly different ($p < 0.05$)

The protein, fibre and mineral contents of BS flour were found to be 29.4, 19.7 and 16.6 g/100 g, respectively, hence suitable for use in enriching wheat-cassava bread to boost their nutritional value. Cassava had significantly ($p < 0.05$) higher content of carbohydrates at 81.0% compared to wheat at 70.7% and BS at 27.6%. The high and low carbohydrates in cassava and bamboo shoots respectively is directly proportional to their energy to protein ratios of 76.0 kcal/g (cassava) and 9.78 kcal/g (BS). Carbohydrate content in a food substance is a major determinant of total energy to protein ratio. Bamboo shoots are generally regarded as low-fat food crops containing 0.3 g/100 g to 3.97 g/100 g wb hence recommended as health food to diabetic, overweight or hyperlipidaemic individuals (Karanja, 2017; Satya *et al*., 2012). Most food blending aiming to enrich various foods with dietary fibre have incorporated carrot, apples, mangoes and cereals like oat and barley. Intake of 25 - 29 g dietary fibre per day has a positive impact on bowel movement, cardiovascular diseases, type 2 diabetes, total serum cholesterol and breast cancer (Santosh *et al.*, 2016). Bamboo is an indigenous food crop that is easily accessible and produces edible shoots. The juvenile shoots contain huge biomass hence can be an alternative source of dietary fibre needed in the enrichment of various food products. The consolidation of dietary fibre in soups, meats, jams, dairy or baked products aim at improving shelf life, prevention of syneresis, textural properties modification and stabilization of high fat foods (Elleuch *et al*., 2011).

4.2 Nutritional Composition of Wheat-Cassava-BS Composite Bread

The nutritional composition of different blends of wheat-cassava-BS bread is shown in Table 4.2. Bamboo shoot incorporation significantly increased the nutritional components of the composite bread. Bread with 10% BS had the highest percentage of minerals, protein and fibre at 4.51%, 26.4% and 5.26%, respectively. There was no significant difference ($p>0.05$) between the energy to protein ratio of 2.5%, 5%, 7.5% and 10% BS composite loaves. Wheat-cassava composite (control) showed very low amounts of dietary fibre of 0.88 g/100 g thus predisposing it to high glycaemic index that induces metabolic and hormonal changes that elevate overeating. Therefore, communities that entirely depend on cassava are likely to suffer from protein-energy malnutrition (Ohimain, 2014). Over 200 million people consume cassava globally hence the need to blend it with food crops like BS that are rich in essential nutrients. The increased amount of dietary fibre in the composite bread has positive effects on bowel function and lipid profile to consumers.

Table 4.2 Nutritional Composition of wheat-cassava-BS bread

Composite bread sample	Dry Matter (%)	Ash (%)	Crude Fat (%)	Crude Fibre (%)	Crude Protein (%)	Total Carbohydrates (%)	Energy Value Kcal/100g	ER (Kcal/g of Protein)
0% BS	72.8 ± 1.12^{a}	0.66 ± 0.13^{c}	1.34 ± 0.09^{b}	0.88 ± 0.10^{c}	1.55 ± 0.24^{d}	68.4 ± 0.84^{a}	293 ± 5.05^{a}	199 ± 31.05^{a}
2.5%BS	71.7 ± 0.62^{ab}	1.87 ± 0.12^{bc}	1.60 ± 0.19^{ab}	2.57 ± 0.61^{bc}	17.0 ± 0.59^{c}	48.7 ± 1.45^{b}	282 ± 2.24^{a}	16.7 ± 0.56^{b}
5%BS	67.6 ± 0.24^{bc}	2.60 ± 0.24^{b}	1.87 ± 0.14^{ab}	2.80 ± 0.51^{bc}	22.6 ± 0.46^{b}	37.7 ± 0.96^{c}	264 ± 0.08^{b}	11.7 ± 0.23^{b}
7.5%BS	67.3 ± 1.52^{bc}	3.98 ± 0.46^{a}	2.01 ± 0.08^{a}	4.09 ± 0.44^{ab}	23.8 ± 0.89^{ab}	33.5 ± 0.19^{d}	255 ± 3.25^{bc}	10.8 ± 0.28^{b}
10%BS	65.8 ± 0.67^{c}	4.51 ± 0.23^{a}	2.06 ± 0.09^{a}	5.26 ± 0.67^{a}	26.4 ± 1.34^{a}	27.5 ± 0.83^{e}	245 ± 3.97^{c}	9.30 ± 0.32^{b}

BS = Bamboo shoot; ER = Energy to protein ratio; values are mean±stdev. Values along the column followed by different superscript letter notations are significantly different ($p < 0.05$)

According to studies conducted by Topping (2013), consumption of value-added bamboo shoot products improved bowel functions and lowered blood cholesterol levels in 8 young women due to high-fibre diet. As such, dietary fibre is considered a functional food containing lignin, oligosaccharides and polysaccharides. Bamboo shoot just like cassava is characterised by low fat ranging from 0.3 g/100 g to 3.97 g/100 g wb hence considered an important food for diabetic and overweight individuals (Karanja, 2017; Satya *et al*., 2011).

4.3 Effects of BS Flour Incorporation on the Physical Properties of Wheat-Cassava-BS Bread

4.3.1 Loaf Volume, Specific Volume and Weight

The outcomes of physical characteristics of the composite bread are presented in Table 4.3. Bread volume is indirectly proportional to its weight and specific volume. Both volume and specific volume significantly decreased ($p < 0.05$) with increase in BS substitution. The range of loaf volume was between 693cm³ - 1303cm³. Loaf volume is directly proportional to specific volume while indirectly proportional to loaf weight. The reduction in volume can be described as a negative impact by non-wheat flours (cassava and bamboo shoot flours) which

Table 4. 3 Physical properties of wheat cassava-BS composite bread

Composite bread sample	Loaf volume (cm^3)	Loaf weight (g)	Specific Volume (g/cm^3)	Crumb L	Crumb a*	Crumb b*	BI
0% BS	1300±12.02[a]	144±0.98[c]	9.08±0.09[a]	75.8±0.35[a]	-2.77±0.07[e]	17.9±1.59[a]	23.6±2.48[b]
2.5%BS	783±3.33[b]	152±1.18[a]	5.15±0.03[b]	62.2±2.11[b]	0.130±0.03[d]	20.3±1.41[a]	38.7±1.76[a]
5%BS	727±13.02[c]	150±1.42[ab]	4.48±0.04[c]	58.3±2.51[bc]	1.40±0.06[c]	19.6±1.10[a]	41.8±1.46[a]
7.5%BS	712±4.41[c]	149±1.19[abc]	4.78±0.01[c]	59.8±0.40[b]	2.03±0.03[b]	20.3±0.55[a]	43.0±1.02[a]
10%BS	693±1.67[c]	146±0.52[bc]	4.75 ±0.03[c]	53.1±0.18[c]	2.83±0.12[a]	18.0±0.38[a]	44.4±1.38[a]

BS = Bamboo shoot; L = Lightness; BI = Browning Index; Values are mean±stdev. Values along the column followed by different superscript letter notations are significantly different ($p<0.05$)

significantly affect the macromolecular network of gluten by disruption and dilution (Koletta *et al*., 2014; Onyango *et al*., 2020). Loaf volume is largely affected by the quantity and quality of protein in the baking flour (Shittu *et al*., 2007). The stronger the gluten holds the carbon dioxide gas released the higher the volume and specific volume of the resulting bread. Both cassava and BS flours lack gluten hence cannot form cohesive visco-elastic network when hydrated. The viscoelasticity which is only exhibited by wheat in this case, allows for formation of typically fixed open foam structure in bread (Sciarini *et al*., 2010). Reduced gluten content results in less elastic and weaker dough since gluten is responsible for dough elasticity as it traps carbon dioxide produced by yeast during fermentation (Wambua, 2017).

These results are similar to various studies that have ascribed this to reduced gluten concentration and its weakness due to blending of different flours (de Alcântara *et al*., 2020; Ho *et al.*, 2013; Mohammed *et al.*, 2012; Sabanis & Tzia, 2009). The undeniable differences in specific volume of the composite bread could be due to factors such as dough rheology, flour blending and pasting properties that directly dictate their processing behaviour (Bakare *et al*., 2016).

However, loaf weight increased up to 5.9% depending on the level of BS incorporation. Major determinants of loaf weight are level of hydration, carbon dioxide diffused out and dough quantity during baking. High bread weight may be attributed to low retention capacity of gas in the composite doughs (Menon *et al*., 2015). The carbon dioxide gas is produced during fermentation and is trapped in the air spaces during fermentation where it causes expansion. During the baking process, starch gelatinization occurs and dough is transformed into elastic crumb (Sengev *et al*., 2013). Thus, it can be concluded that the decrease of refined wheat flour and incorporation of protein rich bamboo shoot flour and high starch cassava flour contributed to bulkiness of the composite flour leading to higher loaf weight. Low loaf weight is unappealing economic characteristic to producers as higher loaf weight tends to attract more customers (Shittu *et al*., 2007). Consumers believe that bread with higher volume and weight has more substance hence willingly purchase it for the same price.

4.3.2 Effect of Bamboo Shoot Incorporation on the Crumb Colour of Wheat-Cassava-BS Composite Bread

The effect of BS flour on the composite bread colour is as shown in Table 4.3. A study has reported the tristimulus CIELAB colour parameters (L*, a*, b*) for various products' crust and crumb (Erkan *et al*., 2006). 'L' values range from 0 to 100 and measures darkness or lightness, a* values indicate redness and greenness where positive values represent red and green represented by negative values, b* values represent yellowness and blueness where yellow shows positive values and blue negative values (Ahmed *et al*., 2000;Jha, 2010). The 'L' value decreased with the increase in the percentage of bamboo shoot inclusion; thus, the control bread had the highest brightness compared to BS enriched bread. However, 'a' which indicates redness increased with increase in BS addition. The various intensity in crumb colours of different loaves is further evident in Figure 4.1 showing the cross-section of each.

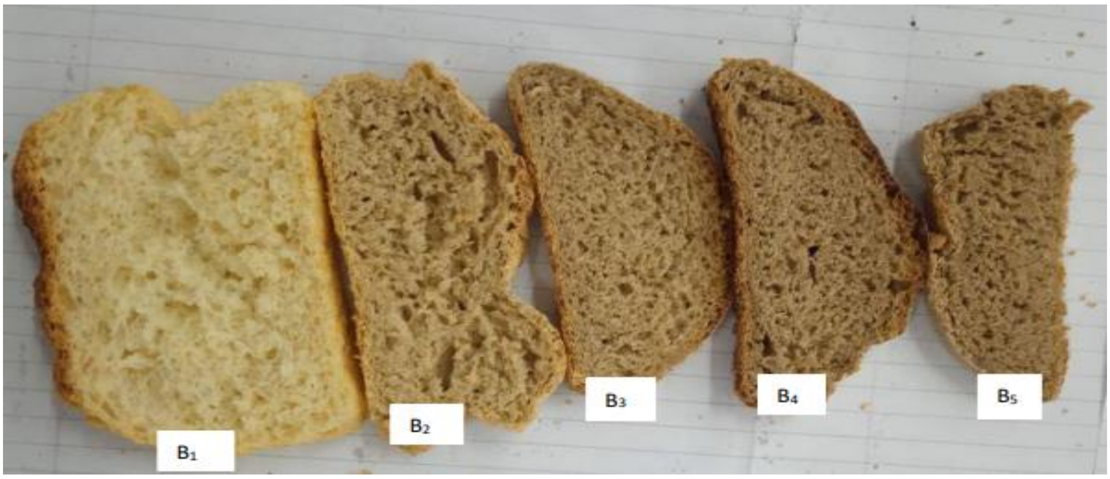


Figure 4. 1 Cross-sections of wheat-cassava-BS composite bread. B_1; 80%wheat: 20%cassava, B_2; 78%wheat: 19.5%cassava: 2.5%BS, B_3; 76%wheat: 19%cassava: 5%BS, B_4; 74%wheat: 18.5%cassava: 7.5%BS, B_5; 72%wheat: 18%cassava: 10%BS

The loaves containing 2.5%, 5%, 7.5%, 10% BS had significantly lower ($p < 0.05$) crumb lightness indices but higher ($p < 0.05$) redness and yellowness indices compared to wheat-cassava bread. The crumbs' BI increased with increase in BS flour incorporation. However, there was no significant difference ($p > 0.05$) in browning index of loaf crumb made from 2.5%, 5%, 7.5%, 10% BS flour. The significant brownness of the crumbs are probably as a result of inherent dark colour of BS flour and non-enzymatic browning of the bread during baking (Bal *et al*., 2011). Similar trends for 'L' and 'a' value have been reported for biscuits fortified with corn-fenugreek flour (Hussein *et al*., 2011), bamboo shoot powder (Choudhury *et al*., 2015) and mango peel powder (Ajila *et al*., 2008).

4.4 Effect of Bamboo Shoot Inclusion on the Rheological Properties of Wheat-Cassava-Bamboo Shoot Composite Flour

4.4.1 Water Absorption Capacity

The effect of incorporating BS in wheat-cassava flour for baking on rheological properties is shown in Table 4.4. The amount of water required to reach the optimum torque of 1.1 Nm by the dough in Mixolab during initial mixing is called water absorption (Sharma *et al.*, 2017). The control had the lowest water absorption of 55.3% compared to composite

Table 4. 4 Rheological properties of wheat-cassava-BS composite flours

Composite bread sample	NFN	WAC (%)	DT (min)	Stability (min)	Softening (Nm)
0% BS	369±0.67[a]	55.3±0.62[e]	2.00±0.36[b]	6.00±0.21[b]	0.120±0.02[c]
2.5% BS	306±0.88[d]	60.4±0.40[d]	2.00±0.36[b]	2.00±0.54[c]	0.130±0.02[b]
5% BS	308±0.67[d]	61±0.27[c]	2.00±0.36[b]	4.00±0.60[bc]	0.130±0.03[b]
7.5% BS	310±0.43[c]	62.3±0.58[b]	2.00±0.36[b]	4.00±0.60[bc]	0.160±0.03[a]
10% BS	319±0.66[b]	63.8±0.62[a]	2.83±0.17[a]	4.47±1.67[a]	0.110±0.02[d]

NFN = Normal Falling Number; WAC = Water Absorption Capacity; DT = Development Time; Cmax = Maximum Consistency; BS = Bamboo shoot. Values are mean±stdev. Values along the column followed by different superscript letter notations are significantly different ($p < 0.05$)

flour containing 10% bamboo shoot which had 63.8%. Increasing the BS percentage in wheat-cassava composite flour significantly increased the water absorption. All the flours were significantly ($p< 0.05$) different. Similar trends have been reported during fortification of fibre rich sources like orange peel (Nassar *et al.,* 2008), mango peel powder (Ajila *et al*., 2008), bran of wheat, rice, oat and barley (Sudha *et al*., 2007), and oat flour (Peymanpour *et al*., 2012) into wheat flour. Water absorption is important in the determination of texture, taste and dough performance when proofing or baking. Studies have reported that the variation in water absorption resulted from substantial hydroxyl groups that exist in fibre structures which permit additional water interaction through hydrogen bonding (Chaplin, 2003; Choudhury *et al*., 2015; Dikeman & Fahey, 2006; Rosell *et al*., 2001). Increased fibre content contributes to dough structural modification thus smaller extensibility, endurance and greater water absorption (Almoraie, 2019). Furthermore, increase in absorption rate could be due to increase in protein solubility, soluble fibre, gelatinized starch and hydrocolloid-like components due to BS addition (Wang *et al*., 2020). As seen in this study, increased BS flour increased the fibre content of the resulting product, thus directly proportional to the flours' absorption capacity. Additionally, weak aggregation power between water molecules and starch molecules increase the surface area for absorption forming hydrogen bonds (Hasmadi *et al*., 2020). Dietary fibre may interact with water by means of hydrogen bonding, polar and hydrophobic interactions, and enclosure. The soluble fibres as a result of BS addition, increases water holding capacity (WHC) and viscosity of the composite dough (Tan *et al*., 2017).

Absorption is a determinant factor for dough consistency and greatly depends on intrinsic factors like protein conformation, amino acid composition and protein hydrophobicity surface polarity.

4.4.2 Normal Falling Number

Addition of BS to wheat-cassava composite flour showed a general decrease of normal FN by 16.8% compared to control (Table 4.4). The bamboo shoots composite flours had lower normal FN ranging from 306-319 compared to control which had 369 . The FN can be defined as a test used to determine the quickness of liquefaction of flour caused by starch α-amylolysis. Falling number values are inversely correlated with α-amylase activity (Struyf *et al.*, 2016). High FN in baking flour indicates low α-amylase activity while low FN shows high α-amylase activity whereby FN < 300 is associated with low economic gain (Shao *et al.*, 2019). Generally, the addition of BS flour in wheat-cassava flour increased the activity of α-amylase in the composite flours due to increased starch. This greatly depends on starch which is a major component of cassava and wheat, an α-amylase substrate and a major cause of flour paste viscosity. Incorporating bamboo shoots into wheat-cassava contributed considerable starch amount hence more substrate for α-amylase thus recording lower FN compared to control. Cereals like wheat are richer in proteins thus have reduced amylolytic activity due to α-amylase deactivation (Codină *et al*., 2019). This is because glutenin retains α-amylase deactivation in quantities that increase as the glutenin enlarges. Also, the rate of starch degradation depends largely on amount of α-amylase in the composite flours and degree of damage of starch.

4.4.3 Dough Softening

Degree of softening also known as mixing tolerance index was observed to increase with addition of BS up to 7.5% BS inclusion (Table 4.4). This increase may be attributed to the presence of fatty acid components like linolenic, linoleic and palmitic acids in BS that interfere with gluten polymeric fraction causing dough softening (Aghamirzaei *et al*., 2018). As softening increased, the dough weakens thus a decrease in tolerance level of dough, attributed to cassava and BS addition. This diluted the glutenin in the composites, weakening the crosslinks between proteins (de Alcântara *et al*., 2020). However, inclusion of bamboo shoot flour up to 10 % reduced the dough softening due to lack of gluten proteins in BS flour that enhance dough elasticity (Abera *et al.*, 2016). The 10% BS flour contributed high amount of fibre content to the composite hence anticipated to be relatively weak. Dough softening could also be explained from the phenomenon of glass transition point of view. Water as a plasticizer reduces dough's glass transition temperature in the compound protein-starch structure (Ahmed, 2015). The water increases the relaxation phenomenon by filling the voids and lubricating the dough thus manifesting a liquid-like nature.

4.4.4 Development Time

Dough development time is the time taken for the dough to achieve optimum elastic and viscous characteristics to ensure essential gas retention for bread making (Ammar *et al*., 2016; Sanchez *et al.*, 2014). The development time for 0%, 2.5%, 5% and 7.5% BS composite flour was constant (2 min) but slightly increased with 10% BS inclusion to (2.83 min) as in Table 4.4. Hence, a significant (p< 0.05) difference between 10% BS inclusion and 0%, 2.5%, 5%, 7.5% BS inclusion. The high dough development time in the 10% BS composite flour was ascribed to hydration properties (evident in its high-water absorption capacity) of the dietary fibre due to high percentage of bamboo shoot inclusion in the composite flour (Onyango *et al.*, 2020). The starch and non-starch polysaccharides are the major non-protein constituent affecting dough rheology. The non-starch polysaccharides form weak secondary bonds with successive gluten breakdown which delay the dough development thus prolonging the development time (Izydorczyk *et al.*, 2001). Abera *et al.* (2016) attributed increased dough development time to increase in the amount of starch damaged and proteolytic degradation of protein in the composite dough. Development time indicates the amount of time required by the dough to achieve its peak resistance to deformation.

4.4.5 Dough Stability

Dough stability can be described as the time required to determine tolerance of flour to mixing as well as its strength. Generally, there was a significant ($p < 0.05$) reduction (2-4min) in dough stability from control (6 min) as in Table 4.4. The stability of various doughs is affected by altered behaviour of water and the extent of gluten dilution (Sun *et al*., 2015). The formation of dough protein matrix can be damaged by supplemental ingredients used in baking, thus may affect dough stability (Marti *et al*., 2014). Other studies have linked dough weakening to high dietary fibre and protein in the dough (Sun *et al*., 2015). Bamboo shoots enriched doughs contain high amount of dietary fibre and protein which negatively influence the well-proportioned protein-starch complexes in the resulting composite bread. The results of this study are consistent with the findings of the study conducted by Aghamirzaei *et al.* (2018) while blending wheat flour and grape seed powder.

4.5 Effect of Bamboo Shoot Addition on Microbial Quality of Wheat-Cassava-BS Bread

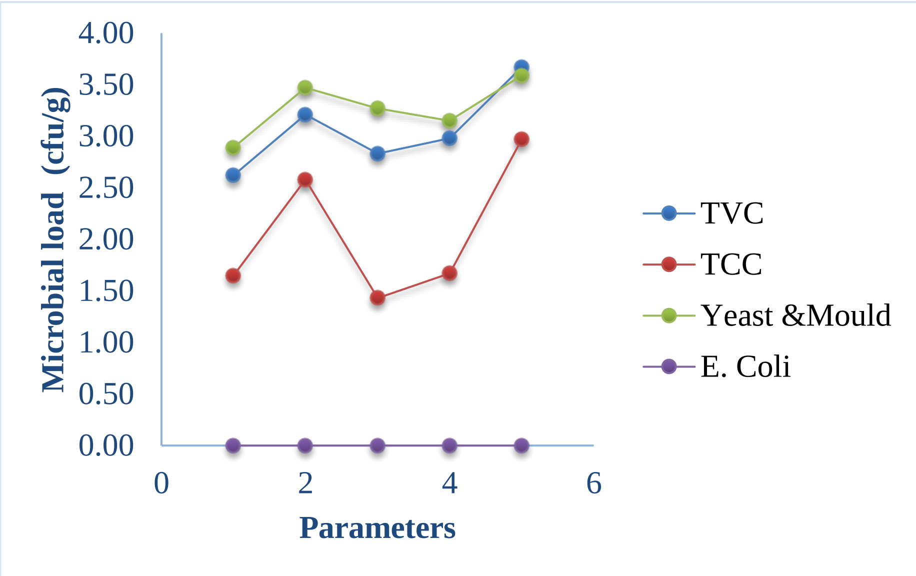
Table 4.5 summarizes the results for microbial analysis of the different composite bread samples.

Table 4. 1 Results of microbiological analysis of wheat-cassava-bamboo shoot bread

Bread samples (cfu/g)					
Parameters	**A**	**B**	**C**	**D**	**E**
Total Viable Count (CFU/g Log10)	2.62 ± 0.59^a	3.21 ± 0.74^a	2.83 ± 0.61^a	2.98 ± 0.42^a	3.67 ± 0.57^a
Total Coliform Count (CFU/g Log10)	1.65 ± 0.44^a	2.58 ± 0.28^a	1.43 ± 0.30^a	1.67 ± 0.33^a	2.97 ± 0.40^a
Yeast and Moulds (CFU/g Log10)	2.89 ± 0.55^a	3.47 ± 0.56^a	3.27 ± 0.52^a	3.15 ± 0.37^a	3.59 ± 0.61^a
E. coli (CFU/g Log10)	NG	NG	NG	NG	NG

A = Control; B =Sample with 2.5%BS; C= Sample with 5%BS; D= Sample with 7.5%BS; E= Sample with 10%BS; NG = No observable growth; values are mean±stdev. Values along the column followed by different superscript letter notations are significantly different ($p< 0.05$)

The total viable count varied from 2.62 cfu/g – 3.67 cfu/g, total coliforms from 1.43 cfu/g – 2.97 cfu/g and yeast and moulds from 2.89 cfu/g – 3.59 cfu/g. However, there was no detection of *Escherichia coli* in the bread samples evaluated. The results, therefore, eliminate the likelihood of faecal contamination in the composite bread samples, a pointer to good hygienic practices during the production process (Ijah *et al*., 2014). The microbial counts were within the standard permissible limits of the Food safety authority. For baked products like biscuits, cakes, and bread, the microbial counts must not exceed; yeast and moulds < 10^4 CFU/g, total viable count < 10^5 CFU/g, coliforms < 200 CFU/g, and *E. coli* absent (Gilbert *et al.*, 2000). Therefore, the study suggests that the composite bread samples do not pose any health concerns to consumers and are safe for human consumption. The bacterial and fungal growth observed in the samples may have occurred during processing from the raw material (composite flour, salt, yeast, or sugar) or preparation equipment. Microbial contamination of a food material can cause serious infection and pose health risks to consumers. Bacterial spores such as *Bacillus* are heat resistant and hence can withstand baking temperatures and thus can prove to be potential pathogens and biological hazards (Pepe *et al.*, 2003). Yeast and moulds had the highest microbial load compared to coliforms and total bacterial counts (Figure 4.2).



TVC= Total Viable Count; TCC= Total Coliform count

Figure 4. 2 Effect of substitution ratio on microbial load (total plate count, total coliform count, Yeast & moulds, *E. coli*) wheat-cassava-bamboo shoot bread.

Spores associated with moulds are destroyed during baking; therefore, it is a major source of spoilage that occurs during post handling contamination, causing public health concerns (Das *et al*., 2020; Saranraj & Geetha, 2012). Reports have shown that moulds are the primary organisms causing spoilage in baked foods, where Eurotium ,Penicillium and Aspergillus, are the most common species (Eleazu *et al.*, 2014). Mycotoxins, toxic secondary metabolites, are synthesized due to the moulds' activity posing serious health threats to humans (Smith *et al.*, 2004). Parameters such as water activity and moisture content levels of samples provide favourable conditions for the growth of microorganisms. They might have been a contributing factor to the observed microbial population. Generally, different microorganisms thrive under different pH, water activity and moisture content depending on their growth conditions. Optimum growth levels are specific to every species of organism.

4.6 Effects of Bamboo Shoot Incorporation on Sensory Characteristics of Wheat-Cassava-Bamboo Shoot Bread

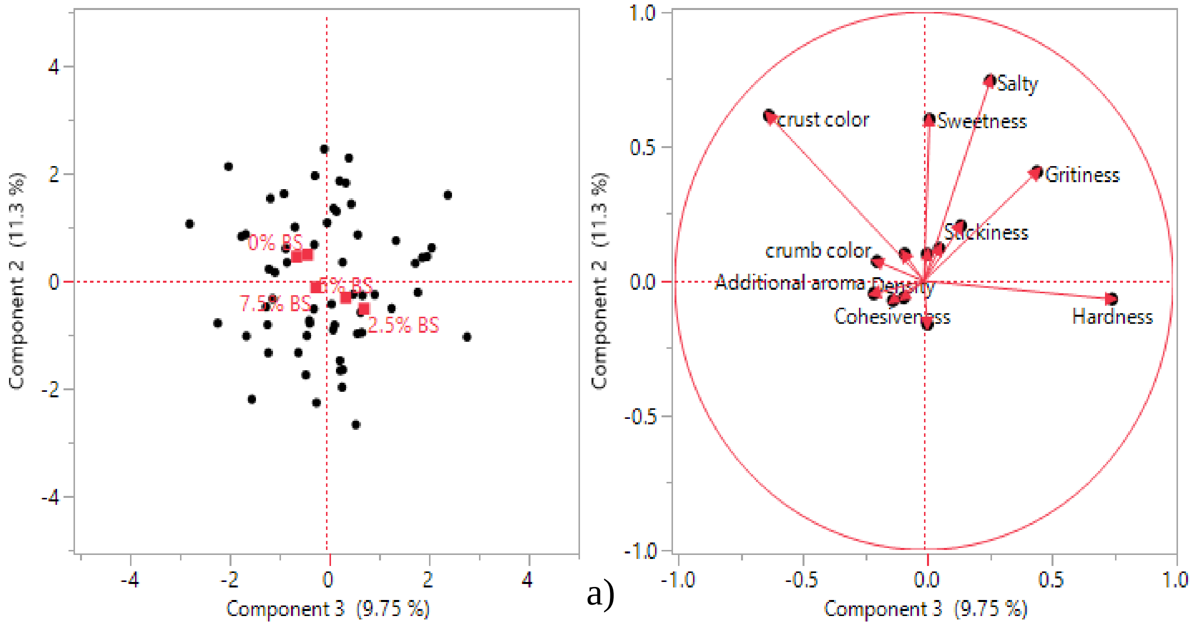
4.6.1 Principle Component Analysis (PCA)

The descriptive sensory data was analysed using PCA, a multivariate data analysis model to outline systematic variations and influential parameters in composite bread attributes. The three principal components explained a total variation of 78.5% in bread samples, as in Table 4.6**.** The outcomes from PCA show the presence of three factors (principle components) for the sixteen sensory attributes of the composite bread. The first, second, and third factors accounted for 57.4%, 11.3%, and 9.75%, respectively. The PCA of composite bread sensory attributes indicated 9.75% variation based on the presence of bamboo shoot flour, while there

Table 4. 2 Principal component factor loading matrix for wheat-cassava-bamboo shoot bread attributes

	Principle Component Scores		
Sensory Attribute	**Factor 1**	**Factor 2**	**Factor 3**
Crust colour			-0.62263
Crumb colour	0.87832		
Density	0.88499		
Baked bread aroma	-0.86521		
Additional aroma	0.89737		
Odour	0.94126		
Hardness			0.75526
Grittiness	0.68718		
Stickiness	0.87622		
Chewiness	0.82237		
Cohesiveness	0.87629		
Aftertaste	0.93984		
Salty		0.74480	
Sweetness		0.60056	
The proportion of the total variance	57.45%	11.3%	9.75%
Total		**78.5%**	

was 11.3% variation due to bamboo shoot flour absence (Fig. 4.3a). The highest variation (57.4%) was due to increased BS incorporation (separated samples based on BS intensity) as in Fig. 4.3b and c. The most predominant sensory attributes that the customers will use to judge the composite bread include crumb colour, aroma, aftertaste, and density. The loadings of original responses on PC1, PC2, and PC3 are summarized in Fig 4.3a, b, and c. The control (0% BS) was associated with sweetness, crust colour, more intense baked-bread aroma, and whiter crumb colour (Fig.4.3a and c). Bamboo shoot bread composites were associated with darker crumb colour, aftertaste, additional aroma, density, cohesiveness, and increased grittiness as the intensity of the BS flour increased (Fig.4.3a,b,c).



a)

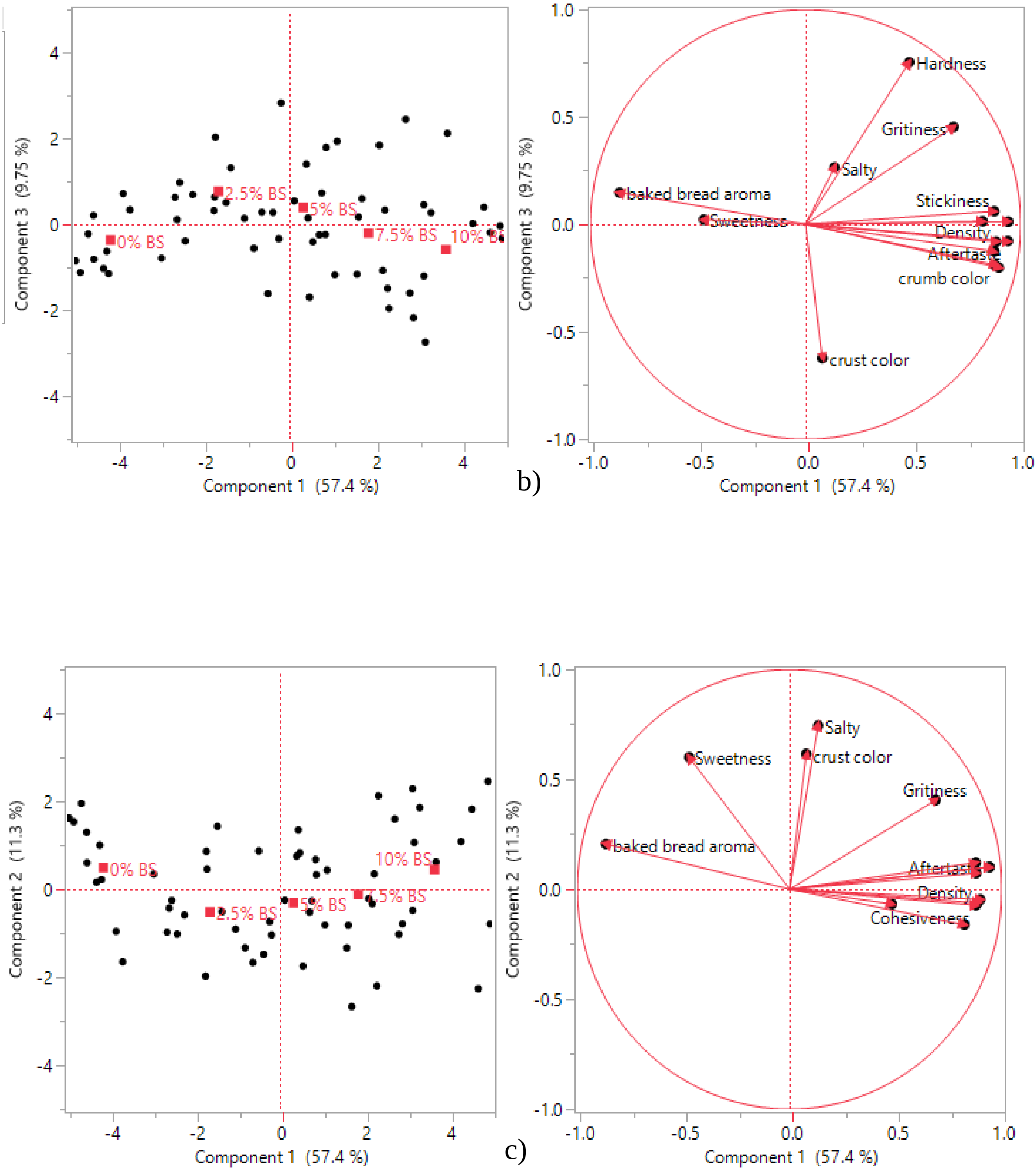


Figure 4. 3. Principal component analysis of wheat-cassava-bamboo shoot bread (a) Plot of the loading factor 2 & 3 and the loading vector from descriptive sensory analysis, (b) Plot of the loading factor 3 &1 and the loading vector from descriptive sensory analysis, c) Plot of the loading factor 2 &1 and the loading vector from the descriptive sensory analysis.

Generally, colour, aroma, and density are important sensory attributes in characterizing bread. Compositing wheat-cassava bread with bamboo shoots impacts substantial brown crumb colour, an inherent BS flour colour. Density, described by the compactness of the air spaces/pores in the crumb, became smaller with an increase in BS flour level. The more pronounced pores in control bread are attributed to gliadin and glutenin, which are responsible for gluten cohesiveness and elasticity when hydrated (Demirkesen *et al*., 2013). During dough expansion, gluten influences carbon dioxide gas retention, developing pores forming crumbly and spongy crumbs (Demirkesen *et al*., 2013; Wieser, 2007). The more compact crumbs in BS bread can be explained by their reduced gluten content hence minimum air entrapment resulting in slightly moist crumbs (Panghal *et al*., 2006). Thus, the composite bread's compactness of the crumb structure is a determinant attribute. Bamboo shoot flour has a significant characteristic smell that quickly replaces the normally baked bread aroma. Therefore, bamboo shoot inclusion at any level greatly influences the aroma of the resulting bread.

Bamboo shoot composites strongly exhibited textural properties like chewiness, stickiness, cohesiveness, and grittiness. Loaves with BS were characterized by gritty residues and stickiness between the teeth when chewed, the roughness of both crust and crumb, and longer chewing time compared to control. The high fibre content in bamboo shoots may have influenced these properties thus entrap water contributing to textural changes. Additionally, the bread components like protein, starch, fat, minerals, and sugars impacted textural characteristics such as crumbliness and flavour (Rathnayake *et al*., 2018). Hardness, on the other hand, is associated with moisture redistribution and dough hydration and occurs in composites due to low gluten matrix, incomplete starch gelatinization, and low expansion of air cells (Loong & Wong, 2018).

The flavour of the composites was described by sweetness and saltiness. Sweetness resulted from bakers' yeast and sugar used in the formulation during the dough fermentation process. This resulted in the formation of volatile compounds known as 3 methyl-1-butanol that contributes aroma and flavour to the bread (Xu *et al*., 2020). At the same time, the strong positive correlation of the aftertaste of composites showed the intensity of bamboo shoot flavour associated with the product.

4.6.2 Consumer Acceptability of Wheat-Cassava-Bamboo Shoot Composite Bread

The effect of substituting bamboo shoot flour for wheat-cassava flour on bread on consumer acceptability is shown in Table 4.7. The results indicated that the control had the highest scores for all attributes tested, followed by 2.5% BS flour. The control and 2.5% BS bread had no significant difference ($p > 0.05$) in terms of taste, aroma, crumb and crust colour, and overall acceptability. Similar studies have shown that an increase in the proportion of bamboo shoot flour in the composite significantly reduced the degree of likeness of baked products like cookies and biscuits. The attributes evaluated included taste, aroma, and overall acceptability, where up to 5% bamboo shoot inclusion was highly acceptable (Giri, 2020; Karanja, 2017; Santosh *et al*., 2019).

Crumb Colour Preference

There was no significant difference ($p > 0.05$) between control and 2.5% BS bread on the mean sensory score for crumb colour. The general decrease in the degree of likeness of crumb colour with an increase in bamboo shoots may be due to the oxidation of sugars (caramelization) during cooking. It was also noted that the brown colour is intrinsically present in the bamboo shoot flour and thus automatically inherited by the composite loaves (Figure 4.4). Colour is a major satisfaction indicator in baked products. The results from this study suggest that the assessors have a different colour preference. Studies have found a direct relationship between the colour of food and its palatability, hence a food requirement when customers demand a particular food (Garber Jr *et al*., 2001; Tamayo & Tamayo, 2020). Incorporating 2.5% bamboo shoot flour into wheat-cassava flour is acceptable to consumers in terms of crumb colour, just the same way they like the control.

Table 4. 3 Acceptability of wheat-cassava-bamboo shoot composite bread as evaluated by consumer sensory panel

Composite bread sample	Taste	Crust colour	Crumb colour	Aroma	Texture	Overall acceptability
0%	3.94 ± 0.15^{a}	4.45 ± 0.12^{a}	4.43 ± 0.13^{a}	4.15 ± 0.14^{a}	4.49 ± 0.09^{a}	4.40 ± 0.09^{a}
2.50%	3.64 ± 0.14^{ab}	3.85 ± 0.16^{ab}	3.98 ± 0.13^{a}	3.87 ± 0.12^{a}	3.89 ± 0.11^{b}	4.15 ± 0.10^{a}
5%	2.68 ± 0.18^{c}	$3.23T \pm 0.14^{bc}$	3.23 ± 0.13^{b}	3.09 ± 0.15^{b}	3.74 ± 0.12^{b}	3.19 ± 0.13^{b}
7.50%	3.11 ± 0.18^{bc}	3.04 ± 0.19^{c}	3.15 ± 0.16^{b}	3.00 ± 0.18^{b}	3.47 ± 0.19^{bc}	3.17 ± 0.18^{b}
10%	2.60 ± 0.17^{c}	2.79 ± 0.20^{c}	3.11 ± 0.18^{b}	2.79 ± 0.18^{b}	3.17 ± 0.17^{c}	2.53 ± 0.17^{c}

values are mean±stdev, Values along the column followed by different superscript letter notations are significantly different ($p < 0.05$)

Texture

There was a decrease in texture preference as bamboo shoot incorporation increased. Bread with 2.5%, 5% and 7.5% BS flour had no significant difference ($p > 0.05$). The control bread had the highest sensory mean score of 4.49. Control had 80% wheat that majorly contains gluten, allowing for the formation of visco-elastic dough that is smoother than pieces of bread containing bamboo shoot flour (Obasi & Ifediba, 2018). Using bamboo shoot flour to enrich wheat-cassava bread increases the bread's fibre content, thus resulting in a sticky, coarse, chewier, and more compact product that proved less desirable to consumers.

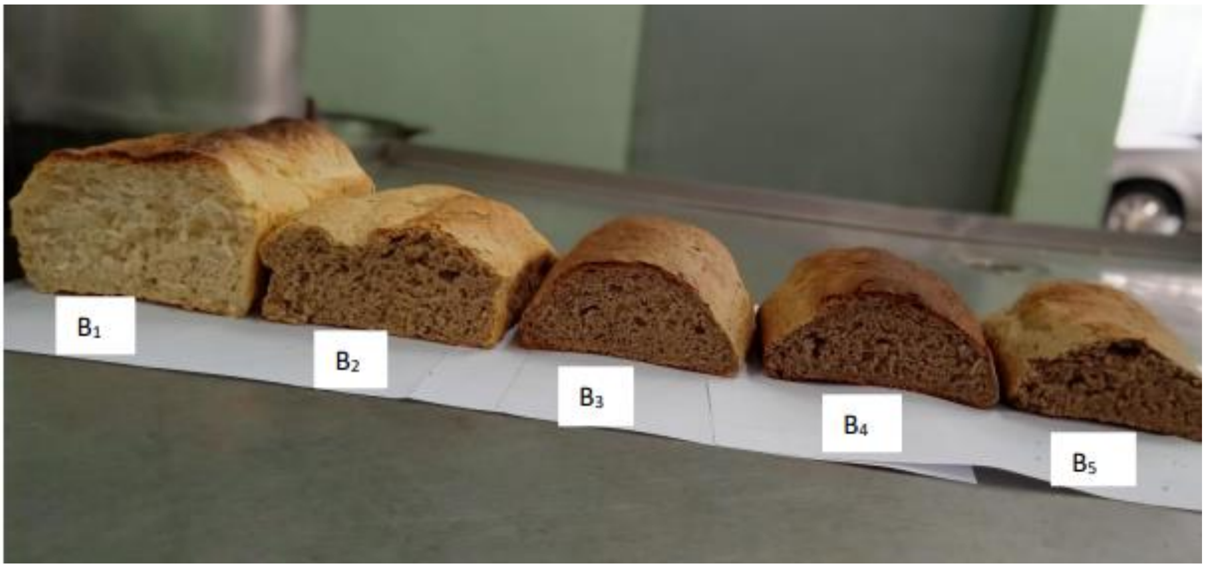


Figure 4. 4 Cross-sections of wheat-cassava-bamboo shoot composite bread. B_1; 80% wheat: 20% cassava, B_2; 78% wheat: 19.5% cassava: 2.5%BS, B_3; 76% wheat: 19% cassava: 5%BS, B_4; 74% wheat: 18.5% cassava: 7.5%BS, B_5; 72% wheat: 18% cassava: 10% BS

Aroma

There was an overall reduction in aroma preference with increased bamboo shoot incorporation. However, there was no significant difference ($p > 0.05$) in the aroma of the control and 2.5% BS composite bread. Most aroma components in bread result from fermentative action by the yeast used as an ingredient during baking. The main odour factors affecting bread aroma during baking are volatile compounds produced during the fermentation process (Cho & Peterson, 2010). This shows that the volatile compound profile obtained from the composite bread may be similar to wheat-cassava bread.

Taste

The control had the highest score for taste with a mean sensory of 3.94, while 10% BS bread had the lowest mean score of 2.6. Generally, there was a decrease in taste preference with an increase in bamboo shoot incorporation. However, there was no significant difference ($p > 0.05$) between the control and 2.5% BS bread. The decrease in taste liking was attributed to the intense aftertaste and slight bitterness caused by high amounts of polyphenols usually present in bamboo shoots (Choudhury *et al*., 2015). Bitterness, aftertaste, and odour influenced the taste of the products, thus affecting consumers' perception. Despite the bitterness that may contribute to unpalatability, polyphenols have powerful antioxidant activity against 1,1-diphenyl-2-picrylhydrazyl radical hence the potential to reduce the risk of chronic diseases (Nirmala *et al*., 2014). Other studies have also linked the bamboo shoot bitterness to the presence of various amino acids like adenine, uridine, L-phenylalanine, L-tryptophan, and L-ornithine, with the greatest contributor being L-phenylalanine (Gao *et al.*, 2019). However, the studies by Zhang *et al*. (2017) unmasked the major determiners of the astringent taste and bitterness in the bamboo shoots as soluble tannins and not bitter amino acids. The bitter sensations of soluble tannins were uncovered to be in the ranges of > 3.0 mg/g, 3.0–1.2 mg/g and < 1.2 mg/g for strong, moderate and mild respectively. Therefore, bamboo shoots can be used to enrich food products at lower percentages (2.5%) that do not alter their palatability.

Overall Acceptability

The overall acceptability decreased with an increase in bamboo shoot percentage in the composite bread. There was no significant ($p > 0.05$) difference in the overall acceptability of bread made with 0% and 2.5% bamboo shoots. This reduction results from the bamboo shoot effect on other attributes such as taste, colour, aroma, and texture. This may be due to increased grittiness, stickiness, aftertaste, darker colour, and bitterness of the composite pieces of bread. A similar trend of reduction in the degree of likeness with an increase in BS flour proportion in terms of taste, aroma, texture, and overall acceptability has been observed in other studies (Choudhury *et al*., 2015; Mustafa *et al*., 2016). From the results, the incorporation of bamboo shoots in bread beyond 2.5% negatively affects consumers' acceptability rate of the composite bread.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. Substitution of wheat -cassava flour with bamboo shoot flour increase the protein, ash, and dietary fibre content of composite bread with an increase in substitution. However, the carbohydrate content, energy value, and energy to protein ratio decrease with increased substitution.
ii. The bread volume and specific volumes decrease with an increase in BS flour percentage in the composite due to wheat dilution. On the other hand, the browning index, water absorption capacity, and dough softening increase with increase in the proportion of BS flour in the blends.
iii. There is no detection of *Escherichia coli* in the bread samples evaluated hence eliminating the likelihood of faecal contamination in the composite bread samples
iv. A reduction in the overall acceptability of the composite bread corresponds to an increase in bamboo shoot aroma, flavour, and aftertaste. Incorporating bamboo shoot flour beyond 2.5% produces a characteristic flavour and taste.

5.2 Recommendations

Based on the findings of the research, the following recommendations are applicable.

i. Developing other baked products like biscuits, cakes, buns, and cookies from wheat-cassava- bamboo shoot flour should be done.
ii. There is a need to conduct experiments on the technological processing improvement techniques for value-added BS products like bread.
iii. It will be necessary to create awareness among Kenyans through nutritional education on bamboo shoots.
iv. Serious hygienic practices must be observed during the entire baking process to prevent post-handling contamination

5.3 Further research

i. Studies on the digestibility of bamboo shoot proteins are necessary.
ii. More studies on the use of suitable commercial flavours or bread spread to mask the bamboo shoot flavour are necessary

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APPENDICES

Appendix A: Selected statistical outputs

Table 1: ANOVA table of physical properties of composite bread

Source of Variation	Degrees of freedom	Loaf volume	Loaf weight	Density	Specific Volume
Composite	4	201485.00***	34.51*	0.01***	10.65
Rep	2	361.67	2.91	0.00	0.01
Error	8	170.00	3.81	0.00	0.01
R^2	-	0.99	0.83	0.99	0.99
CV	-	1.55	1.32	1.19	1.39

Key: R^2 = Coefficient of determination, CV = Coefficient of variation , * = Significant at $p < 0.05$, ** = highly significant at $p < 0.01$, ***= highly significant at $p < 0.001$

Table 2: ANOVA table of colour properties of composite bread

SOV	DF	Lightness	a*	b*	Hue angle	Chroma	BI
Sample	4	194.44***	5.26***	13.62***	5590.52***	14.18**	158.09***
Part	2	353.93	111.04	220.47	4382.98	226.00	3080.06
Rep	2	3.65	0.004	1.11	0.05	0.99	26.09
Sample*Part	8	174.50	13.50	9.69	5570.33	8.73	337.76
Error	28	7.99	0.20	2.82	1.70	2.70	15.79
R^2	-	0.93	0.98	0.89	0.99	0.88	0.96
CV	-	4.79	14.76	7.25	1.84	6.98	7.31

Key: SOV= source of variation, DF = degree of freedom, R^2 = Coefficient of determination, CV = Coefficient of variation , a* = redness, b* = yellowness, BI= browning index * = Significant at $p < 0.05$, ** = highly significant at $p < 0.01$, ***= highly significant at $p < 0.001$

Table 3: ANOVA table of the nutrient composition of wheat, cassava, and bamboo shoot flours

SOV	Df	DM	Ash	Fat	Fibre	Protein	CHO	EV	EP
Ingredient	2	46.88*	219.32***	2.51*	381.27***	465.05***	2407.64***	4165.69***	3668.77***
Rep	2	4.34	0.004	0.03	1.58	2.04	9.72	118.66	51.22

Error	4	3.90	0.12	0.10	1.58	0.35	0.93	33.08	28.09
R^2	-	0.88	0.99	0.93	0.99	0.90	0.90	0.98	0.99
CV	-	2.17	5.13	23.77	18.80	3.62	1.61	1.74	14.56

SOV= Source of variation; Df = Degree of freedom; DM = dry matter; CHO = carbohydrates; EV= Energy value; EP = Energy to protein ratio

Table 4: Correlation between calorimetric (bread samples) and Rheological(flour) properties

	L	a*	b*	Hue Angle	Chroma	BI	NFN	Absorption	DT	Stability
L	1.00	0.72^{ns}	0.58^{ns}	-0.94*	0.60^{ns}	-0.69^{ns}	0.96**	-0.86^{ns}	-0.07^{ns}	0.14^{ns}
a*		1.00	-0.20^{ns}	0.59^{ns}	-0.15^{ns}	071^{ns}	-0.58^{ns}	0.78^{ns}	0.26^{ns}	0.22^{ns}
b*			1.00	-0.57^{ns}	0.99***	0.14^{ns}	0.51^{ns}	-0.58^{ns}	-0.38^{ns}	-0.15^{ns}
Hue angle				1.00	-0.62^{ns}	0.54^{ns}	-0.99**	0.90*	0.24^{ns}	0.004^{ns}
Chroma					1.00	0.13^{ns}	0.56^{ns}	-0.58^{ns}	-0.35^{ns}	-0.11^{ns}
BI						1.00	-0.64^{ns}	0.42^{ns}	0.41^{ns}	-0.45^{ns}
NFN							1.00	-0.83^{ns}	-0.07^{ns}	0.15^{ns}
Absorption								1.00	0.56^{ns}	0.37^{ns}
DT									1.00	0.96^{ns}
Stability										1.00
Softening										
Cmax										

Key: L= lightness, a* = redness, b* = yellowness, BI= browning index, DT= development time, NFN= normal falling number, Cmax= maximum consistency, * = Significant at $p < 0.05$, ** = highly significant at $p < 0.01$, ***= highly significant at $p < 0.001$, ns= not significant

Table 5: ANOVA table of nutritional properties of wheat-cassava-bamboo shoot composite bread

Source of Variation	Df	DM	Ash	Fat	Fibre	Protein	CHO	Energy Value	Energy to Protein
Composite	4	27.84**	7.33***	0.28*	8.20**	297.29***	775.91***	1178.95***	201485.00***
Rep	2	3.03	0.23	0.07	1.37	3.68	4.51	43.98	361.67
Error	8	2.60	0.20	0.04	0.62	1.48	2.21	31.60	170.00
R^2	-	0.85	0.95	0.80	0.88	0.99	0.99	0.95	0.99

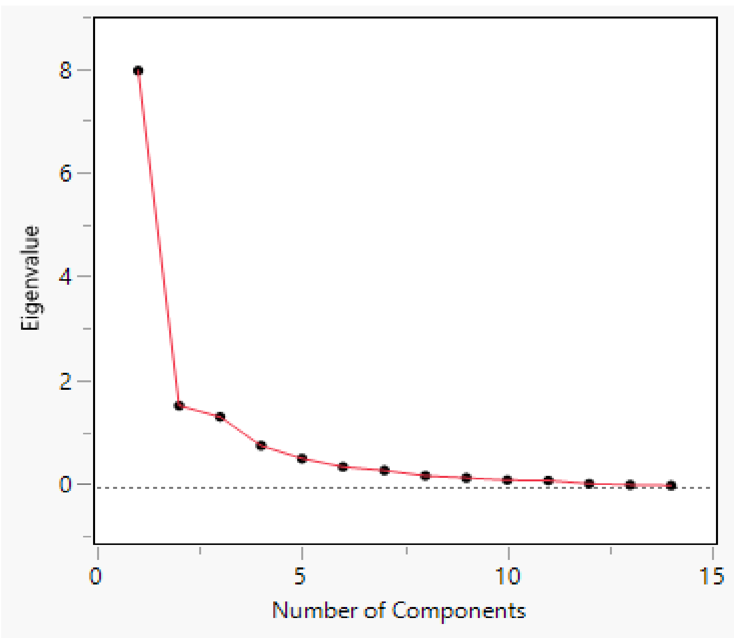
CV	-	2.33	16.60	11.29	25.15	6.66	3.44	2.1	1.55

Df = Degree of freedom; DM = dry matter; CHO = Carbohydrate

Table 6: Eigenvalues from Principle Component Analysis

Number	Eigenvalue	Percent	Cum Percent	ChiSquare	DF	Prob>ChiSq
1	8.0416	57.440	57.440	841.521	87.771	<.0001*
2	1.5831	11.308	68.748	397.478	88.515	<.0001*
3	1.3652	9.752	78.499	312.496	77.098	<.0001*
4	0.8135	5.811	84.310	212.152	66.461	<.0001*
5	0.5641	4.029	88.339	152.022	55.660	<.0001*
6	0.4054	2.896	91.235	110.176	45.637	<.0001*
7	0.3355	2.397	93.631	81.615	36.744	<.0001*
8	0.2319	1.656	95.288	54.698	28.555	0.0023*
9	0.1915	1.368	96.656	40.039	21.241	0.0081*
10	0.1497	1.069	97.725	27.457	14.727	0.0226*
11	0.1396	0.997	98.722	18.494	9.317	0.0347*
12	0.0782	0.559	99.281	3.800	5.242	0.6110
13	0.0560	0.400	99.681	0.597	2.216	0.7859
14	0.0446	0.319	100.000	0.000	.	.

Scree plot



Appendix B: Research output

- Conference presentation

Home / Archives / Egerton University 14th Biennial International Conference / Transformative Agri-food Systems

EVALUATION OF THE PHYSICO-CHEMICAL PROPERTIES F COMPOSITE BREAD PRODUCED FROM WHEAT, CASSAVA AND BAMBOO SHOOT FLOURS

Dorsilla Nyamai
Egerton University

Keywords: nutritional value, bamboo shoots, composites

Published
01-04-2022

Abstract

The need to combat food insecurity and malnutrition has seen industries focus on enriching indigenous staple foods with locally available nutritious underutilised food crops. Bamboo shoot (BS) has drawn significant global interest owing to its high nutritional content and health promoting compounds. This study evaluated the rheological properties of composite flours, and physico-

- Publication in a peer reviewed journal (Manuscript 1)

Journal of Food and Nutrition Sciences
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Sensory Evaluation of Wheat-Cassava-Bamboo Shoot Composite Bread

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Received: May 30, 2022; **Accepted**: June 15, 2022; **Published**: June 27, 2022

Abstract: With the numerous studies pertaining to bamboo shoot utilisation, little have been explored on the bread baking industry and general consumption in Kenya. The objective of this study was to conduct descriptive sensory and consumer acceptability analyses on wheat-cassava-bamboo shoot composite bread. Bamboo shoot flour was composited with wheat: cassava (80:20) at different levels of 0% (control), 2.5%, 5%, 7.5%, 10% and used to make composite bread. In descriptive sensory analysis, Principle Component Analysis (PCA) was used to outline systematic variations in bread sensory attributes. The results of PCA showed the existence of 3 principle components that explained a total variation of 78.5%. The PCA of composite bread sensory attributes indicated 9.75% variation based on the presence of bamboo shoots flour while there was 11.3% variation due to bamboo shoot flour absence. The highest variation (57.4%) was due to intensity of bamboo shoot flour in the bread. Consumer acceptability test was conducted using a 5-point hedonic scale and involved 50 semi-trained panellists. The study found out that 2.5% bamboo shoot flour bread had no significant difference ($p > 0.05$) in terms of taste, aroma, crumb colour, crust colour and overall acceptability compared to control. However, there was gradual decrease in consumer acceptability of all the attributes tested with increase in proportion of bamboo shoot flour. A substitution level of up to 2.5 bamboo shoot flour in composite bread on overall acceptability was indistinguishable to the control bread; hence has

- **Manuscript 2**

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 22 No. 9 November 2022 AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2022; 22(8): 21418-21436 https://doi.org/10.18697/ajfand.114.22315

FUNCTIONAL AND PHYSICOCHEMICAL PROPERTIES OF WHEAT, CASSAVA, AND BAMBOO SHOOT COMPOSITE FLOURS AND BREAD

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ABSTRACT

The need to combat food insecurity and malnutrition has seen industries focus on enriching indigenous staple foods with locally available nutritious but underutilised food crops. Bamboo shoot (BS) is one such crops that has drawn significant global interest owing to its high nutrient content, health-promoting elements and low fat. This study aimed at evaluating the proximate composition, physicochemical, and functional properties of wheat-cassava-BS composite flours and their respective loaves of bread. Five levels of BS (0, 2.5, 5, 7.5, and 10%) were substituted for wheat-cassava using 80:20 percent wheat: cassava mixture as control. The flours were analysed for water absorption capacity, Normal Falling Number (NFN) and dough softening. Bread samples were baked from each of the formulated composite flours and analysed for nutritional composition and physical properties. Water absorption increased with an increase in BS substitution while there was a reduction of 16.8% in the normal falling number from the control. Dough softening increased with an increase in BS inclusion up to 7.5%. All the bread made from BS flour had significantly different ($p < 0.05$) physical properties (loaf volume, density, specific volume, and Browning Index (BI) from the control. However, the crumb BI for all the BS composite-bread samples were not significantly ($p > 0.05$) different. Bamboo shoots had 16.6% ash, 19.7% fibre, 29.4% crude protein, and the lowest energy-to-protein ratio of 9.78 kcal/g. The proximate components of the blended bread increased with an increase in BS substitution. Composite flour with 10% BS had the highest total ash, crude fibre, and protein at 4.51%, 5.26%, and 26.4% compared to the control that had 0.66%, 0.88%, and 1.55%, respectively. Results of this study show that BS flour can be blended with wheat-cassava composite to increase BS utilisation and improve the nutritional value of developed products, thus providing diversification in bakery products.

Key words: bamboo shoots, composite bread, cassava, physicochemical, functional properties, proximate composition

I………………………………………………… have voluntarily agreed to take part in this study. I understand that I will not directly benefit from this study. I have explained the study to me, and I understand that it entails sensory evaluation of bread samples. My participation in this study involved tasting the bread and profiling the predetermined sensory properties according to my perception of the standards. I confirm that I am not allergic to bread and do not have any issue consuming a food product containing wheat. I understand that the results will be kept anonymous after the examination and will be treated confidentially. My identity will remain anonymous after the study, which will be done by coding my details.

……………………….   …………………………

Signature of participant   Date

…………………………

Signature of researcher

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

II. Score sheet for a 5-point hedonic scale for the consumer acceptability test

Name of Panellist …………………………… Phone no.…………………………….

Date…………………….

Instructions:

You are provided with 5 coded samples. You must score and record each sample as per your judgment of the attributes listed on the left side of the table in the appropriate box. Key: **1-Extremely dislike, 2-Dislike, 3-Neither Like nor Dislike, 4-Like, 5-Like Extremely**.

Attribute	**SAMPLE CODES**				
	KLM	**CBY**	**PQS**	**DRL**	**JYN**
Texture					

Crust colour					
Aroma					
Crumb colour					
Taste					
Overall acceptability					
Comments (if any)					

III. Score sheet for a Descriptive Sensory Evaluation test

Name ………………………………………. Panellist no ………………………………

Date ……………………………………………………………………………….

- **Please rinse your mouth before starting.**
- **Evaluate the product before you by looking at it, feeling it, and tasting it.**
- **Assign an appropriate score (1 being the least and 7 being the most) for each of the listed parameters/components.**

Bread specific evaluation

APPEARANCE

Crust Colour: The colour of the sample crust

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

White **Brown**

Crumb Colour: The colour of the sample crumb

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

White **Brown**

Density: compactness of the air spaces/ crumb cell number

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

Small number **Large number**

AROMA

Baked bread aroma: Aroma typical of cereals mixed with boiling water.

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	None						**Intense**

Additional aroma**:** aromatic characteristics as a result of bamboo shoots incorporation

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	None						**Intense**

Odour intensity: associated with rancid smell or staleness

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	Less						**Intense**

TEXTURE

Hardness: the associated force required to first bite throughout the sample with the molars

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	Soft						**Hard**

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

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**

KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

None **High**

Stickiness: the degree to which residues stick to the teeth.

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

None **High**

Chewiness: Number of chews required before swallowing.

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

Small number **Large number**

Cohesiveness: The degree to which the chewed sample holds together

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

Crumble **Compact**

TASTE

Aftertaste: associated with bamboo shoot flavour

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	Less						**Intense**

FLAVOUR

Salty: associated with iodized salt.

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	Less						**Intense**

Sweetness: associated with sugar perceived from baked products.

Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**
KLM	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
CBY	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
PQS	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
DRL	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
JYN	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**
	Less						**Intense**

Appendix D: NACOSTI Research authorization

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **384575**

Date of Issue: **27/November/2021**

RESEARCH LICENSE

This is to Certify that Ms.. Dorsilla Auma Nyamai of Egerton University, has been licensed to conduct research in Bungoma, Homabay, Nakuru on the topic: EVALUATION OF QUALITY PROPERTIES OF BREAD PRODUCED FROM WHEAT, CASSAVA AND BAMBOO SHOOT COMPOSITE FLOURS for the period ending : 27/November/2022.

License No: **NACOSTI/P/21/14497**

384575

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