DEVELOPMENT OF PROTEIN AND MINERAL ENRICHED CASSAVA ROOT-MILLET-COWPEA LEAVES COMPOSITE FLOUR FROM SELECTED POPULAR CASSAVA VARIETIES IN KILIFI AND TAITA-TAVETA COUNTIES, KENYA

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DEDICATION

This dissertation is dedicated to my family for their continued financial, spiritual and moral support. My friends Grace Nyatichi, Tobias Aduda, Cavin Ojijo, Sam Koile, Lydia Kimuma and Samuel Ondiege who have been very supportive throughout the entire period.

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LIST OF ABBREVIATIONS

CPIA Carbohydrate for Protein Isolate of Cowpea

DDCF Dehulled Defatted Cowpea Flour

ESA East and Southern Africa

FAO Food and Agricultural Organization

GPF1 Famila porridge flour sold locally

GPF2 Green Porridge formulation 1 with varied proportions of cassava millet and cowpea leaves

GPF3 Green porridge formulation 2 with varied proportions of cassava millet and cowpea leaves

GPF4 Green porridge formulation 3 with varied proportions of cassava millet and cowpea leaves

IITA International Institute of Tropical Agriculture

KALRO Kenya Agriculture and Livestock Research Organization

PICS Purdue Improved Crops Storage

UN United Nations

WHO World Health Organization

GENERAL ABSTACT

Food and nutrition insecurity is a major challenge in Kenya today and especially at the Kenyan coast (Kilifi and Taita-Taveta counties). Cassava roots a drought resistant crop rich in carbohydrates is grown at the Kenyan coast intercropped with cowpea leaves, millet, banana, pigeon peas, coconut and banana. Globally, the crop feeds more than 800 million people and thus if promoted has the potential of solving food and nutrition insecurity at the Kenyan coast. The current study sought to determine the current utilization and processing levels of cassava roots. The study further sought to determine effect of processing on the nutritional composition of local varieties of cassava roots, cowpea leaves and millet, grown along the Kenyan coast and then formulate an enriched cassava roots-millet- cowpea leaves composite flour based on local food crops.

In July 2018 carried out a field survey where 250 respondents participated. The study used a pre-tested semi-structured questionnaire to determine the current utilization and processing levels of cassava roots along the Kenyan coast. Samples of three popular cassava roots and millet were collected from Kilifi and Taita-Taveta counties. The study determined the nutritional composition of the raw materials while subjecting them to pre-treatment processes to ensure a prolonged shelf-life of the respective samples. Milled flour composed of cowpea leaves, millet and cassava roots was formulated into composite flours. The blended composite flour were sensory evaluated by 50 panellist who had training on scoring of various parameters. The formulated flour were further subjected to shelf-life determination while monitoring yeast and moulds, moisture content, Acid and peroxide value.

The study established that there is a gender balance in farmers who grow cassava in Taita-Taveta (56.9% males) and Kilifi county (54.4% females). There was a significant association ($P \leq 0.01$) between growing cassava for income and receiving any form of training on cassava, which empowered farmers to increase economic value of cassava farming. The cassava crop is mostly grown by farmers (40%) aged 36-50 years. Processing of cassava roots into dried chips has the potential of increasing the storage life of the crops from being highly perishable to have a longer shelf life.

The cyanide content of cassava varied with treatment, raw 7.8-9.5, dried 3.4-5.0, and dried fermented 2.2-2.8 ppb. The carbohydrates content was in the range of 35-37, 81.73-83.49 and 70.28-71.20% for raw cowpea, cassava and millet respectively; the carbohydrate content for unfermented flours was in the range of 35.68-35.19, 66.07-83.49 and 66.07-68.89% for cowpea leaves, cassava roots and millet respectively; the carbohydrate content for the fermented flours was in the range of 29.06-28.01, 79.68-84.36 and 69.08-70.12% for cowpea leaves, cassava roots and millet, respectively. The protein content was in the range of 25.69-26.01, 1.2-18 and 11.1-13.3% for unfermented cowpea, cassava and millet flours. Fermented flours protein content was in the range of 25.7-29.3%, 1.3-2.2%, 8.5-11.1% cowpea, and cassava and millet flours respectively. Iron and zinc content ranged 431.8-90ug/kg, 100-130.54 ug/kg for raw cowpea leaves; 798.2-789.7ug/kg, 121-125ug/kg for unfermented cowpea leaves flour; 658-823ug/kg, 99.2-122.3ug/kg for fermented cowpea leaves flour.

Green porridge formulation two (cassava roots 50: cowpea leaves 30: millet 20) had the highest color score and 5.18 ($p<0.05$). The score indicates a near equal acceptability of the flour based on color when compared to the already retailing famila flour. Green porridge formulation three was the least accepted flour. Green Porridge Formulation three had the highest total aerobic count of

3.7 log cfu/g and the acid value of the flours ranged from as low as 1.84±0.01mg KOH/g for GPF2 at day zero and as high as 12.88±1.73 mg KOH/g at day six of accelerated shelf-life. The formulated flours had protein (8.0%) Fat (3.5%) carbohydrates (70%), Zinc (58.8ug) Iron (62.3ug) and vitamin C (24.4mg) which gave more than 40% of the recommended daily intake.

The processing of cassava roots, millet and cowpea minimizes post-harvest losses, while adding commercial value to the crop. The development of protein and mineral enriched composite flours of cassava roots-millet and cowpea leaves has the potential to contribute towards the realisation of a food and nutrition secure global community. The study recommends commercialization of the formulated flours as it has potential to increase the income of the local farmers while at the same time ensuring a positive step towards the realization of a food and nutritionally secure global community.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Agriculture is the main activity that provides incomes and livelihoods in Africa (World Bank, 2008). Cassava is one of the drought-resistant crops that has the potential of giving high yields consistently (Chandrasekara & Josheph Kumar, 2016). The crop is quite adaptable to a varied range of climates and can thrive in as low as 400mm per annum of rainfall and as high as an average temperature of 29 degrees Celsius.

In line with the mission of International Institute of Tropical agriculture (IITA), there is need to redirect a million hectares of land for sustainable agriculture and cassava is at the center of this as a potential crop for use (Ohimain, 2014). Africa is unable to cope with the increasing population and so food security remains elusive where 243 million people of the 815 million chronically undernourished in the world live (FAO et al., 2017). Of this global figure, 20% malnourished people are in Africa where Eastern Africa contributes 33.9% (FAO et al., 2017). In Africa, cassava crop is often produced in small-scale farms or at the backyard of households. In Nigeria, the crop has been utilized for quite a long time in making products such as Gari and fufu. To spur and stabilize the Gross Domestic Product of Nigeria and to reduce the overdependence in oil, the former president of Nigeria, Olusegun Obasanjo initiated a presidential campaign to upscale the production of cassava (Lamboll *et al*., 2018).

In the East and Southern Africa (ESA) region, about 70% of the population live in the rural areas where agriculture is the main source of livelihood with little or no opportunity to diversify incomes from non-farm activities (Tadele, 2012; Setimela *et al.*, 2004). In the same region, 40% of the people live on less than US$ 1.25 per day (Tadele, 2012; IFAD, 2013). This threatens the achievement of the Sustainable Development Goals on reducing hunger and poverty among the worlds' poor and vulnerable population mainly in Africa (IFAD,2013). African heads of States reaffirmed their commitment to these challenges through Agenda 2063.

Improving human wellbeing and livelihoods and adapting to climate change requires that rural poverty and food insecurity be addressed. There is need to enhance the role of the smallholder farmers who manage 80% of the worlds' small farms and contribute 80% of the food consumed in the world. Cassava is a major source of carbohydrates. Globally, cassava serves as the third most utilized source of carbohydrate, coming after maize and wheat (Chandrasekara & Josheph Kumar, 2016). The cassava root crop, however, is deficient of major minerals and vitamins limiting its utilization as a nutrient dense crop. The protein content of the plant is also quite low. The cassava crop contains cyanide and tannin, anti-nutrients which are potential carcinogens and major nutrient inhibitor, respectively (Gacheru et al., 2015). The consumption of cassava, especially the bitter variety has often lead to death especially during the famine.

Food and nutrition insecurity is very common in the Kilifi and Taita-Taveta counties. Mugalavai (2018) Kenya Government listed Taita-Taveta and Kilifi counties amongst the counties suffering food insecurity. This was with the intention to supply counties with food rations to temporarily avert the hunger crisis (Mugalavai, Kinyua, & Yabann, 2018). Up to 62% of the Kenyan Coast population are is poor (Odhiambo et al., 2014). This has a direct negative impact on childbearing women and children under five who are most affected by malnutrition. In Kilifi County, the main carbohydrate source is cassava (Mugalavai et al., 2018). In Taveta sub-county, cassava is ranked amongst the top five most preferred crops while in Taita the crop has high potential but farmers lack adequate technical training on preservation and processing of cassava roots to minimize post-harvest losses (Abong *et al*., 2016). Cassava has high potential to serve as food which could lower the high pressure on maize as the most dominant food (Muoki, 2015).

Increased commercialization of cassava, has seen the starch in the tuber processed to produce industrial starches (Uchechukwu-Agua, Caleb, & Opara, 2015). The crop is used to make cassava flakes and crisps. Nigeria at the moment exports cassava baked products, such as bread, which contains 40 % cassava flour (Ohimain, 2014). There is need to come up with composite flours (cassava-millet-cowpea leaves), this shall increase the utilization of the crop, shelf-life and availability of the cassava-based products.

Cowpea leaves and millet are grown within the tropical countries (Kotey, 2014). The crops are grown as cassava intercrops along the Kenyan Coast. Cowpea leaves are a rich source of proteins (28%), vitamins and minerals (Animasaun, Oyedeji, Mustapha, & Azeez, 2015). The crop is grown for its seeds and leaves. The cowpea leaves have been utilized as vegetables and prepared by boiling, stewing, frying and fermenting (Okonya & Maass, 2014a).

Pearl millet is a rich source of plant fat, iron, zinc and carbohydrates (Singh, 2016). The crop grows and does well in a wide range of climatic conditions. The pearl millet has been utilized by milling into flour and consuming as porridge (Awolu, 2017).

1.2 Problem Statement

Cassava as one of the starch-rich plants has gained popularity as a staple food in most households in Africa especially in the West Africa regions and currently in the Kenyan Coastal region. Despite its low nutrient value, cassava roots are consumed daily in the coastal area as the major food giving children only carbohydrates thus posing a threat to the growth and development of the children (World Health Organization, FAO 2016). The high levels of intake of cassava in Eastern, Central Africa and Southern parts of Africa is the most likely cause of Konzo in young people (Nhassico et al., 2016). The occurrence of Konzo can be traced back to the utilization of cassava with high levels of cyanide. Equally, in the western parts of Africa particularly in Nigeria, the long-term utilization of gari is the most likely cause of TAN in the older people.

Cassava with a short shelf-life of about 5-7 days poses a great challenge to the farmers when it comes to storage (Zainuddin et al., 2018). The shelf-life becomes even shorter if proper harvesting procedures are not adhered to. At the Kenyan Coastal region, there is a high level of malnutrition in children under the age of five due to overdependence on cassava as a meal (Odhiambo et al., 2014). There is limited information on nutritional changes, acceptability and shelf life of a composite flour from cassava and cowpea leaves. This project, therefore, sought to determine and document the nutritional composition changes of cassava roots, cowpea leaves and pearl millet while subjected to various pre-treatment processing (washing, peeling, dying, milling, fermentation). The study further sought to establish and document the acceptability and shelf-life of the varied cassava roots-millet-cowpea leaves composite flours.

1.3 Justification

The development of a more nutritious composite flour of cassava and cowpea leaves would aid in expanding the range of products developed from cassava. With the increased product diversification, the crop will attract more uses such as extraction of starch from the dried chips hence an increased demand for cassava which eventually translates to increased production of cassava. The increased production of cassava will not only ensure an increased supply of food but also contribute immensely towards eliminating the increasing incidence of famine due to the deficiency in maize supply. The up-scaling of cassava production will also lead to a reduction in pressure on other cereal grains such as wheat and maize. With the diversification of the product and increased demand, there is an increased revenue generation and thus a better or improved welfare of the local cassava farmers.

The cassava crop has a wide adaptability to adverse climatic condition. Kenya is more than 75% ASAL and thus promotion of cassava growth shall bring the idle lands to productivity. The information generated through the current study shall inform policy makers, the Ministry of health, Non-Government Organisations, Industries and farmers on the need to incorporate cassava flours with other nutrient rich crops such as cowpea leaves and millet.

1.4 Objectives

1.4.1 General Objective

The general objective of the study was to develop a nutritious cassava-cowpea composite flour from locally grown cassava roots, millet and cowpea varieties along the coastal region of Kenya.

1.4.2 Specific Objectives

1. To determine the current utilization of cassava and cassava products at farm level in Kilifi and Taita-Taveta counties.
2. To determine the nutritional composition of local varieties of raw cassava roots millet and cowpea leaves.
3. To determine the effect of pre-processing treatments on the Nutritional composition and cyanide three popular cassava varieties, cowpea leaves and millet grown along the Kenyan coast
4. To determine the physico-chemical characteristics of locally grown cassava roots-millet-cowpea flours
5. To determine sensory quality and shelf-life of cassava roots-millet-cowpea composite flours

1.5 Hypotheses

1. There are no variation in the current utilization methods of cassava and cassava products at farm level between Kilifi and Taita-Taveta counties.
2. There are no variations in the nutritional composition of local varieties of raw cassava roots, millets and cowpea leaves.
3. There are no variations in pre-processing treatments on the Nutritional composition and cyanide three popular cassava varieties, cowpea leaves and millet grown along the Kenyan coast
4. The formulated blended flours do not differ in physico-chemical properties
5. There are no variations in the sensory quality and shelf-life of cassava roots-millet-cowpea composite flours

CHAPTER TWO: LITERATURE REVIEW

2.1 Cassava Crop

Cassava (*Manihot esculeta*) is one of the crops that is grown globally; in South America, Brazil is one of the leading growers of the crop (Andersson, 2017). China produces over 230M tons of the crop for use in the production of biofuel as well as other industrial uses. Thailand is one of the leading exporters of the crop and its products on the global platform (Gupta & Verma, 2015). In Africa, the crop is quite popular in the west, in countries such as Nigeria and Ghana. In Eastern Africa, Uganda has commercialized the production of Cassava and currently, the farmers are supplied with clean cultivars for the plantation to help curb the increasing disease attack on the crop (Paul Odhiambo et al., 2018). In Kenya, the crop is grown in the Western parts of the country and the Eastern provinces. Although the crop is not highly commercialized, the crop has been grown in Taita-Taveta, Kilifi, Kakamega, Busia, Migori and Homabay counties (Mugalavai et al., 2018).

Cassava Crop has characteristics that make the plant adaptable to a wide range of growth conditions making the plant an household name in the arid and semi-arid areas moreover the farms of low-income families or small-scale farmers (Chandrasekara & Josheph Kumar, 2016). The plant does well on nearly all type of soils however the crop does well in sandy, clay and loam soils provided the soils are well drained and with little or no fluctuating water table (Chandrasekara & Josheph Kumar, 2016). The crop can yield highly in both alkaline and acidic soils and thus a pH range of 4-8 would facilitate the growth of the crop. The crop, however, requires an optimal soil pH of 5.5-6.5. Although the crop is highlighted as one of the least responsive to climatic change, the crop requires a rainfall that is well distributed throughout the growing period. The rainfall range should be 1000-1500mm but the crop also does well in rainfall as low as 400 mm

(Chandrasekara & Josheph Kumar, 2016). The crop is quite sensitive to shade and this affects greatly the yields when the crop is grown under such conditions (Lamboll et al., 2018). The crop does equally well in the drought-prone areas and in the moist environments. However, in the moist environment care has to be taken to ensure the crop is planted in well-drained soil since cassava does not tolerate flooding (Streck et al., 2014). In drought-prone areas cassava shades some leaves to lower water loss which are rebuild in the rainy season. For maximum root production, the plant requires a temperature range of 25-32 degrees Celsius (Streck et al., 2014). The plant is quite tolerant to acid soils –and has developed a symbiotic relationship with soil fungi which helps its roots to absorb more nutrients (Streck et al., 2014). The plant is efficient in water utilization. And is often grown in tropical regions (Chivenge, Mabhaudhi, Modi, & Mafongoya, 2015).

There are two major categories of the cassava crop, the sweet variety, and the bitter variety. The categorization is based on the levels of cyanide in the crop (Hershey, 2017). According to Kenya Agriculture and Livestock Research (KALRO), common cassava varieties that are grown in the country include Tajirika, Shibe, karibuni, Nzalauka, and Karemba. These varieties have been reported to do so well along the Kenyan coastal region (KALRO, 2018).

2.2 Post-harvest handling and losses of cassava

Developing countries, to ensure food security, cassava amongst other drought-resistant crops was highlighted as potentials (Beeching & Enny, 2018). Enny, (2018) notes that cassava came top among the potential top crops that could help solve food security menace. The utilization of this starch-rich product is, however, limited due to post-harvest physiological deterioration, a major constraint in the production of the crop (Gupta & Verma, 2015). The short shelf life of the product due to the rapid post-harvest physiological deterioration discourages major players in the cassava value chain from selling the product and thus limits its utilization (Uchechukwu-Agua et al., 2015).

Most nations, have cassava roots sold to the consumers while yet the roots are still fresh. The fresh roots have a relatively shorter shelf-life. The post-harvest deterioration causes both economic and physical loss of starch quality of the fresh cassava roots (Abong et al., 2016a). Quality is greatly reduced when spoilage sets in (Abong et al., 2016a), thus rendering the crop roots unpalatable and subsequent reduction of market value (Aditya, 2018). Critical loss of the roots occur during sun drying and stalk pilling at both the market and farm level. Post-harvest physiological damage is often due to mechanical damages during harvesting of the roots (Zainuddin et al., 2018).

Processing of cassava into various food forms has a potential of reducing the extent of post-harvest losses of the roots (Aditya, 2018). Noticeably in the massive cassava producing nations, the fresh cassava roots are processed into Gari, Fufu, dried chips, and high-quality flours. These products enhance the stability and long-term storage life of the roots thus ensuring the availability of the roots and increased economic value (Aditya, 2018).

2.3 Nutrient Composition of Cassava

Cassava a staple food often grown in the tropical and subtropical regions of Africa is a rich source of carbohydrates and is one of the highly consumed root tubers as compared to other root tubers (Zainuddin et al., 2018). The crop has certain advantages over the other root crops considering it gives high yields. Furthermore, the crop is easily propagated and exhibits a commendable pest and disease resistance. It is mostly grown by small-scale firms to provide both carbohydrates and proteins nutritional value (Oloruntola, Agbede, Onibi, & Igbasan, 2015). In as much as the protein levels are low, there is a trending increase in bio-fortification of the cassava flour with richer sources of proteins and other mineral constituents (Mugalavai et al., 2018). The leaves of cassava have indicated a source of most minerals including vitamin B1 and B6. The leaves are a good source of trace elements and even calcium. According to a study done by Somendrika et al., (2017) noted the levels of Phosphorous and Sodium in the leaves of cassava were relatively low.

A study done by Albert Linton Charles indicated that cassava contains about 9.2-12.3 % moisture content, about 1.2- 1.8 % crude protein. Linton Charles noted that the levels of crude lipid and crude fiber were within the ranges of 0.1-0.8 and 1.5 – 3.5 respectively. The levels of ash in the same study were at 1.3 – 2.8. The study further affirmed that cassava is a rich source of carbohydrates by recording high carbohydrate levels of 80.1- 86.3 %.

Despite the nutritional composition of cassava being better than the other root tuber, the crop contains certain anti-nutrients with a possibility of either having a positive or a negative impact on an individual's health depending on relative amounts consumed (Olapade, Babalola, & Aworh, 2014). Some of the anti-nutrients included antioxidants (exhibiting a positive effect) as well as anti-carcinogens and thus exhibiting a positive impact too. The anti-nutrients normally interfere with the absorption and utilization of certain nutrients and thus may have a side effect on the human body. The level of cyanide in cassava has created a "cyanide scare" associated with acute intoxication in cases where substances rich in cyanide are consumed; however, through a study conducted by Ayodeji et al, 2017 stipulated that a combination of certain processing methods tend to alleviate the scare as the levels of Cyanide become significantly reduced. The cassava leaves have high levels of tannin. The levels of tannin in cassava are quite high than the corresponding levels in the leaves of other cereal grains and legumes. The level of tannin (which is high) affects the digestion of their nutrients considering the possibility of tannin binding with the other nutrients to form indigestible complexes.

2.4 Cyanide in cassava

The consumption of food that is rich in nutrients, safe and is hygienically prepared is an emerging concern in most parts of the world. Currently, the consumers have become much aware of the need to not only get a food to the table but also take into consideration the nutritious levels of the foods as well as the safety of the food. Cassava, despite being the third most consumed source of carbohydrates in the globe, the plant contains certain anti-nutrients with tannins and cyanide being the dominant anti-nutrients (Gacheru et al., 2015). Cyanide content is high in the parenchymal tissues of cassava and in the roots; the levels of cyanide are higher on the peels (Fayemi & Ojokoh, 2014).

According to a study done on 6 locally grown varieties of cassava on the levels of cyanide, the levels were relatively high. On the fresh tubers, the levels of cyanide were < 30mg HCN kg-1. In the study, despite the significant variation of the levels of cyanide in the different cultivars, the average analyses of the recently grown cultivars gave an average of 13-27mg HCN. The levels of the cyanide in the varied varieties triggered the need to analyse the environmental factors affecting the occurrence and distribution of cyanide in the cassava plant.

A similar study done to analyse the levels of the anti-nutrients in the cassava rich root tubers also indicated the high levels of both cyanide and tannins in the leaves and the roots of the plant. The plant which is basically grown for the roots as a source of nutrients has its leaves also consumed. Despite the plant having linamarase, an enzyme that neutralizes the impacts of the cyanide by neutralizing it to a less acutely toxic substance through hydrolysis care the consumption of the leaves need to be monitored to avoid any incidences of toxicity. The condensed tannins and cyanide found in the leaves adversely affect the quality of the meals. Condensed tannins are also high in the forages. When such forages are incorporated into animal feed, the quality of the feeds is adversely affected. The incidence has been greatly identified when such a feed is fed to the egg-laying hens. The impact of the high levels of tannins is evident in the rate of reduction in laying of eggs by the chicken feed in meals subsidized with cassava. Equally, tannins reduce digestibility by inhibiting the digestive enzymes and altering the permeability of the gut. Thus in the consumption of such a meal, it becomes essential to process the cassava purposefully with the intention of lowering the levels of this anti-nutrients I.e. the levels of cyanide and condensed tannin.

In a study to evaluate the levels of tannins in a composite flour of cassava and tiger nuts, the levels determined using the SWAIN method, the tannin levels were significantly high (Oresegun, Fagbenro, Ilona, & Bernard, 2016). Therefore, there is the need to process the cassava to lower the corresponding levels of tannins. The contents of tannin in a high-quality cassava-tiger nut blended flour ranged from 3.06±0.04 to about 6.09±0.10% which is still quite high. The levels of cyanide in both sweet and bitter cassava varieties when subjected to various processing treatments indicated a similar trend. The levels of the cyanide in the leaves of the low cyanide type indicated a very high enzymatic activity during the early growth stage (period of < 3 months) and in the high cyanide cultivar root peel linamarase activity become greatly reduced during the growth cycle. The bitter cassava varieties are relatively high yielding and thus it is necessary to incorporate or to boost the levels of linamarase in such varieties to optimize the cyanide scare in the consumers. Tannins also have a stringent property that hastes the healing of wounds and preservation of decay.

2.5 Products made from cassava

Cassava which is also known as *Manihot esculenta Crantz* is normally processed into a variety of food products worldwide for over a century. Both the traditional and contemporary methods using technology have been adopted to obtain several useful products of cassava. The attributes of cassava such as spoilage, cyanide content, nutrient content, root yield, and process ability have been suited by the methods adopted. In a world of increasing population especially the third world countries, there has been increasing demand by the consumers to have quality foodstuff and increase new usage of cassava (Mwizerwa et al., 2017). This has led to the transformation of indigenous methods of cultivation and cassava processing to modern scientific knowledge in industrial use.

Basically, Cassava is made into both fermented and non-fermented products. The fermented products include: fermented cassava flour, starch, cassava bread, fufu, and gari .On the other hand, unfermented products include cassava chips, tapioca, pellets, unfermented starch, and flour (Uchechukwu-Agua et al., 2015).

2.6 Importance of Cowpea crop

Cowpea (Vigna unguiculata) is an important arid and semi-arid legume that grows over a wide range of climates. The crop is a good source of energy protein, minerals, dietary fibre, and vitamins. The crop is also a good source of phosphorous and thus a more nutritious vegetable (Gonçalves et al., 2016). The crop which is famously grown for its grains, the consumption of the leaves is gaining fame in the households. The crop has a nutritional composition of 22-32.5% protein, 2.9 to 3.9% of ash and a fat content of about 1.4- 2.7% and of cause the plant is a good source of carbohydrates with about 59.7-71.6% on wet weight basis (Okonya & Maass, 2014a). The crop grown mostly for edible seeds is currently becoming popular for its leaves which are a rich source of proteins (International Institute of Tropical Agriculture, 2014). The leaves are consumed by both humans and animals. The leaves have traditionally been served dried and currently are dried and preserved for utilization during periods of scarcity. The protein content of the leaves ranges from 29-43% on a dry weight basis with a higher nitrogen content in the young leaves, thus for better and more nutritious meals, it is recommended that the young leaves be consumed. According to a study done in Ghana, the nutrient composition values of the cowpea leaves on a dry weight basis is quite a good standing at about 9.4- 13% for moisture content, 303.8-468.9 mg /100g for phosphorous and at the same time the leaves are a good source of vitamin C (Gerrano, Adebola, van Rensburg, & Venter, 2015). The ascorbic leaves according to this study ranged from about 33.5 -148.0 mg/100g. In the study, a total of 15 varieties were studied and the amount of protein on a dry weight basis ranged between 27.1 to 34.7%.

Although the leaves of cowpea and even the seeds are good sources of proteins, the leaves do contain a significant level condensed tannins. Tannins do occur in legumes and cowpea is no exception (Pimenta Barros, Salgado, Melo, & Biazotto, 2014). The levels of tannins which are at a significant level are a concern to the nutritious quality of the leaves and this is due to the deleterious nutritional effects of dietary tannin. The minimum amount of dietary tannins needed to elicit negative growth response are yet to be established and thus the leaves can still be consumed as long as they are prepared efficiently to reduce the level of tannins (Oresegun et al., 2016). Breeding is currently underway to ensure the production of easy to cook beans with reduced levels of tannins (Animasaun et al., 2015). A study on sensory scores for taste conducted in Ghana indicated that there was no any significant variations in terms of taste of the different varieties. But the levels of acceptability correlated with the leaf size.

2.7 Nutrient composition of cowpea

The nutritional composition of cowpea is rich. A study done by Mbah & Silas, (2010) using iso-electric (CPIA) precipitation and micellization (CPIB) stipulated that cowpea leaves had crude protein (70%), total ash of 2%, and 60% carbohydrate for protein isolate of cowpea. (CPIA) and CPIB showed crude protein of 72%, 2.4% total ash and 15% carbohydrate protein. The protein concentration in cowpea flour (WCF) was 20% and 30% in Dehulled Defatted Cowpea flour (DDCF). Amino acids available according to amino acid analysis done were Valine, Lysine, Leucine, and phenylalanine (Mbah & Silas, 2010).Most of the protein component of cowpea are derived from them, however, the leaves do contain to a significant level some condensed tannins. Tannins do occur in legumes and cowpea is no exception. The levels of tannins which are at a significant level are a concern to the nutritious quality of the leaves and this is due to the deleterious nutritional effects of dietary tannin.

2.8 Post-harvest handling and losses in cowpeas leaves

2.8.1 Threshing

Once harvesting has been done, the pods of cowpeas are manually threshed using beating sticks when harvested pods have been sun-dried (Mbah & Silas, 2010). The pods can also be removed by the fingers to remove the seeds especially when the quantities are not so much.

2.8.2 Sorting

Sorting is also vital to remove defective broken grains, stones, waste and infected seeds (Mbah & Silas, 2010). Most seed dealers had the interest to get clean seed from seed farmers in order to get better pay (Mbah & Silas, 2010).

2.8.3 Packaging

The seeds ought to be packaged in bags and put into an electric dryer or spread on a slab in the sun to make sure moisture content from the seed is reduced to the desired level (Kotey, 2014). Hence: cowpeas should be packaged in suitable places which are clean, safe and free from insect, fungal infestation. The packaging equipment should be of good grade quality. The packaging material should safeguard nutritional, hygienic, technical qualities. The packaging bags should be free from pests and other contaminants and free of any toxic or undesired smell (Kotey, 2014). The same type of cowpeas should have the same designation (Mbah & Silas, 2010).For extended period storage of cowpea, the Purdue Improved Crops Storage (PICS) containers should be used. This helps to reduce cowpea grain loss to insect infestation.

2.9 Products made from cowpea

Cowpea is one of the most vital starchy or dry pulse legumes produced in most parts of Sub-Saharan region of Africa. It is believed to have originated from Sub Saharan Africa. However, its importance has been appreciated in most parts of the globe such as Asia and certain parts of America because of the products made from it. A study done by Mbah & Silas, (2010) showed that cowpea products are a common food item in most parts of the United States especially the Southern parts where it's often called the Black eyed peas. Two subcategories of the black-eyed peas are the Squamish and Cream cowpeas. The study noted that some of the products made from cowpeas included: Akara, Moin, and other dishes, baking with flour blends and weaning foods.

2.9.1 Processing as a means of reducing cyanogen in cassava

Although the cassava tubers are a rich source of carbohydrates and the crop is the third best source of starch consumed globally, the cop contains highly toxic cyanogen compounds and certain anti-nutrients (Abdullahi, 2014). The cassava tubers contain cyanogenic glucosides which have about 95 % linamarin and about 5% Lotaustralin. The other compounds are the cyanohydrins and the free cyanide. There are attempts to reduce the levels of these toxic compounds in the tubers. Through the careful and effective processing of the cassava tubers, the level of cyanide can be greatly reduced to ensure the cassava are safe for consumption. For instance according to WHO guidelines, for one to produce a flour of cassava of 10mg HCN equivalents/kg, the safe level requirement for sun drying or an alternative of fermentation (heap) provides a protocol where one has to start with a sweet cassava variety with an average of about 12-33 ppm total cyanide.

This often poses a challenge when it comes to the high-level cyanide cassava variety (Emmanuel et.,). The challenge, therefore, possesses a necessity for developing internationally accepted standards for permissible levels or the maximum recommended residual levels of cyanogen in cassava products.

Cassava consumption has been linked with cyanide toxicity.(Burns, Bradbury, Cavagnaro, & Gleadow, 2012) To avert such toxic incidences which are sometimes acute or chronic certain preparation are set in place to reduce the levels to a maintainable level. Boiling, steaming, baking and deep drying have been reported to significantly reduce the levels of both blanched and the raw cassava chips. The procedure has been adopted as one of the cheap alternative ways of preparing the cassava tubers for household consumption. The reduction in total cyanogen is adversely affected by the enzymatic decomposition of cyanogenic glucosides (Burns et al., 2012). The cyanogenic glycosides which are highly soluble in water do in most cases get leached in the water used for the boiling of the tubers. The effectiveness of the cyanogen reduction processes is an interplay of the sequence of the methods used as well as the duration of each of the treatments. Sun drying, oven drying are some of the most effective methods of ensuring the levels of cyanide in the cassava root tubers are greatly reduced. Another alternative set of procedures include steaming, shredding steeping and or a combination of the processes, this equally reduces the levels of the cyanogen in the compounds to be within a safe level for human and animal consumption. The residual levels of cyanogen glycosides and their toxic degenerative products i.e. the cyanohydrins and the free cyanide in the cassava products or the processed products depend on the initial level of the cyanogenic glucosides and the type of reduction procedure utilized as well as the time of exposure to the different procedures. Tannins when heated do undergo irreversible changes. The irreversible nature of the reaction makes it possible for the levels of tannins to be efficiently reduced when the cassava is heated at 60 degrees Celsius. Boudeox et ., al 2003 studied the impact of oven drying on the levels of tannins in cassava and according to this study oven drying at 60 degrees became quite efficient and effective in ensuring that the levels of cyanide in the crops were significantly reduced. And the levels of tannins are greatly retained at a temperature of 70 with an increased retention as the temperatures tend to 100^{o}C.

2.9.2 Gaps in knowledge

Despite cassava roots being one of the rich sources of starch, the level of commercialization of the crop is relatively low, there is no definite structured market for the cassava roots as well as the cassava products (Abong et al., 2016a). The level of bio-diversification of the product is still quite low and thus the crop is majorly grown in small-scale farms due to the low demand thus the need to upscale the production of the crop (Lamboll et al., 2018). At the moment there are no documented recommended maximum residual levels of cyanide in cassava and cassava products. Although fermentation of cassava has been done before, the perfect combination of processes to reduce the level of cyanide is not documented (Abong et al., 2016a). The rate of product bio-diversification still needs to be improved to ensure maximum utilization of the crop and contribute towards enhancing the market for the products. There is the equally low rate of capacity building in regards to cassava as a crop, the rate of commercialization and market for the cassava products. The lack of enough knowledge by most farmers is a setback towards the upscaling of the crop (focus group discussion). There is no documented formulation of cassava composite flours to improve the nutritional composition of the flours (Abdullahi, 2014).

CHAPTER THREE

UTILIZATION AND PROCESSING OF CASSAVA ROOTS ALONG THE KENYAN COASTAL REGION- CASE STUDY OF TAITA-TAVETA AND KILIFI COUNTIES

3.1 Abstract

Cassava is utilized both as food and raw material for industries and hence is important for economic reasons and food and nutrition security. A cross-sectional baseline survey was conducted in Taita-Taveta and Kilifi counties along the Kenyan coast, using semi structured questionnaire administered purposively to cassava crop farmers. The study sought to determine the socio-demographic characteristics, the cassava cultivation, post-harvest practices and utilization of cassava roots. The results indicate a shift from a female dominated agriculture to a gender equity (Taita-Taveta 56.9% males and Kilifi 54.4% females). The crop is grown in small portions of land (under 1 acre) and intercropped with cowpea leaves, maize, pigeon pea, coconut and beans. Most farmers prefer whole farm harvesting (92%) and immediate sales due to limited knowledge and lack of training on processing techniques. The most used preservation method is the on-farm method (crop in garden) in Taita-Taveta (50%) and Kilifi (51%). Cassava products consumed were chips, crisps, dried chips with flour being the most utilized. The flour is in combination with other crops is made into delicacies such as kimanga (a local coast dish). Limited value addition coupled with lack of ready markets is a constraint for cassava production in Kilifi and Taita Taveta. The roots should be processed to ensure minimal post-harvest losses.

3.2 Introduction

Cassava, a drought tolerant crop, is a source of livelihood to the people of Kilifi and Taita-Taveta counties which are located along the Kenyan coastal region (Chivenge et al., 2015). The crop which is quite tolerant to the extremes of temperature, drought and poor soil has often been one of the coastal farmers' preferred crop (Chivenge et al., 2015). According to IITA (IITA, 2016), up scaling production of the crop is prioritized as one of the organization's agenda in promoting the use of idle Arid and Semi-arid Lands. The crop, which gives high yields, if well promoted would impact significantly in raising the living standards (Mugwe, Immaculate, Mucheru-muna, & Mugendi, 2015) of the households in this counties and even Kenya as whole. In Kenya, in line with the Big Four Agenda, two of the fundamental goals are to ensure food security and job creation (Odhiambo et al., 2018).

Cassava being the world's third best source of starch, it is of interest to researchers and policy makers to establish the levels of current utilization and levels of processing especially in regions where the crop has been grown. According to KALRO, there has been significant research on the crop in terms of breeding to raise high yielding and fast maturing varieties such as Tajirika, Shibe, Kaleso, Kibandameno and Nzalauka (KALRO, 2015). However, there is no proper documentation of the levels of adoption and appreciation of these improved varieties by the Kenyan farmers. Following the long drought between 2016 and 2017 along the coastal region, there are high chances that the farmers may have lost all the stored cuttings. Thus, the present study sought to establish the current utilization and level of processing of cassava roots along the Taita-Taveta and Kilifi counties with a view to informing the policy makers when making decisions in line to promoting and up-scaling the production of the cassava crop.

The cassava crop is inadequately processed in Kilifi and Taita-Taveta counties (Abong et al., 2016a). The crop which is grown in small scale by the farmers is majorly processed into crisps and dried chips for flour (Uchechukwu-Agua et al., 2015). There is need to further processes cassava roots into industrial starch. The Kenyan government has identified the cassava crop for promotion in the quest to be food and nutritionally secure(Paul Odhiambo et al., 2018).

3.3 Materials and methods

3.3.1 Study area

A cross-sectional survey was conducted in the two counties of Kilifi and Taita-Taveta located along the Kenyan coastal Region. The two counties are known to be among the largest producers and consumers of the cassava roots with agricultural activities as the backbone of their economies (Taita-Taveta County, 2018). Small-scale farming and pastoralism are the major economic activities. According to the 2009 census, Kilifi County has a population of about 1,217892, while Taita-Taveta has a population of 284,657 people with an approximated 82.6% residing in the rural area (KNBS, 2018). The rainfall in the two counties is scarce and inconsistent. Kilifi, located at 30-310 m above sea level experiences an annual rainfall of 700 -1300 mm while Taita-Taveta which is located at 500 – 2700 m above sea level, has an annual rainfall of about 1500-1700 mm (Koskei, Felix; Kariuki, Sicily; Ntiba, Micheni; Sigor, n.d.). The two counties are located along the Kenyan coastal region. Figure 3.1 shows the geographical location of Kilifi and Taita-Taveta counties. The map is retrieved from Google (2019).

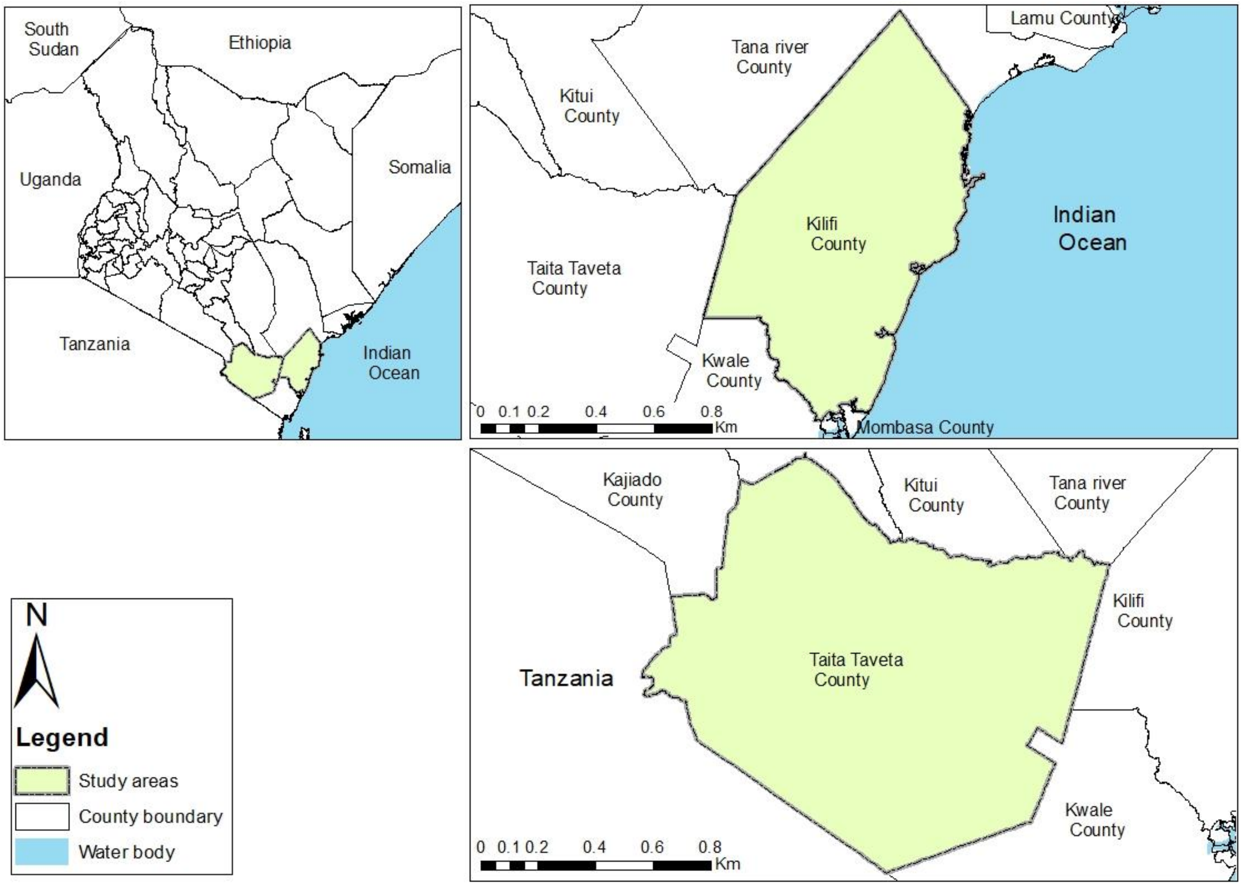

Figure 3. 1 Map of Kilifi and Taita-Taveta counties. Source: Google (2019).

3.3.2 Study Design

The current study utilized a cross- sectional survey model to collect data on the utilization of the cassava roots, in Kilifi and Taita-Taveta counties. Each of the counties two sub counties were purposively selected for being the dominant cassava growers based on focus group discussion held in July 2018. The total number of responds were 250 and each county had 125 respondents who were further subdivided into the wards of origin.

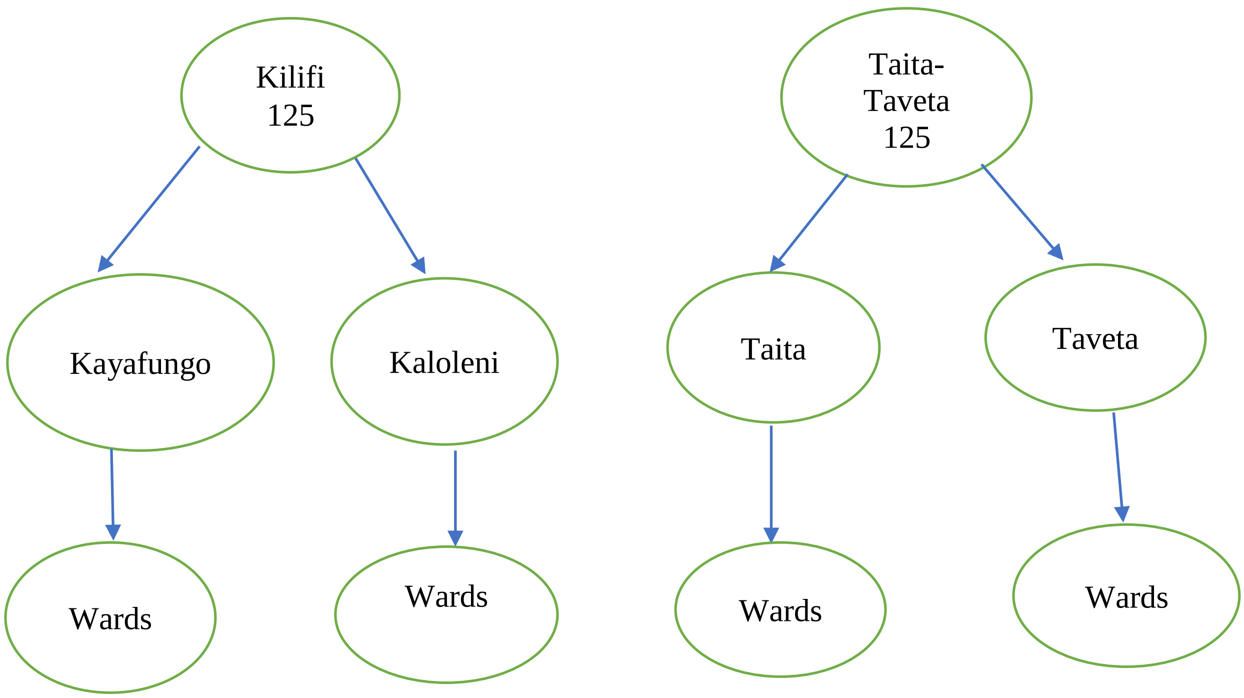

Figure 3. 2 Study Design illustrating the criteria of respondents' selection

3.3.3 Sample size determination

Fisher's formula (Israel, 2003) was used to determine the sample size (Odhiambo et al., 2014).

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where

n_o is the sample size,

Z= 196, p= 0.2 and q equals 0.8 and e= 0.05 p= the proportion of farmers growing Cassava

Therefore, $_{no}$ = $(196^2 * 0.2 * 0.8)/0.05^2$

Thus, a total of 245 farmers were to be interviewed, however, the current study used 250 respondents with 125 respondents from each county.

3.3.4 Sampling procedure

The survey was done form July 7 to July 15, 2018, and it entailed administering of semi-structured questionnaires to the farmers. The regions and the respondents were purposively selected based on their history of cassava production and thus utilization. During the survey, two sub-counties in each county were targeted and cassava consumers interviewed. A total of 250 farmers from the two counties were interviewed. The study capitalized on face to face mode of communication, and the administered questionnaires had been adjusted following a pre-testing and initial focus group discussions done in the two counties in April of 2018.

3.4 Data Analysis

The data were analysed using SPSS version 21. The means and frequencies were used to summarize the data collected on socio-demographic information, post-harvest of handling of the crop as well as the different products and utilization level of the products. The Pearson chi square coefficient r was used to test for the relationship between the social demographic characteristics and the growth characteristics of the cassava crop**.**

3.5 Results

3.5.1 Demographic characteristics of farmers in Kilifi and Taita-Taveta Counties

The socio-demographic characteristics of respondents indicated that, a majority of the farmers were female (54.4%) in Kilifi County while for Taita-Taveta majority were males (56.9%). In both Counties, most of the farmers were aged 36-50 with, 32.4% and 49.6% for Kilifi and Taita-Taveta counties, respectively. In Kilifi, the youth were second largest respondents (32%) while for Taita-Taveta persons aged > 60 years were the second largest group (19%). In Kilifi County, a majority of the respondents had Primary Education (59.6%) while the least respondents had Tertiary education (1.5%). In Taita-Taveta, 60.2% of the respondents had primary level education, while 9.8% of the respondents had tertiary education. In Kilifi County, 83.7% of the farmers were married with 10.4% of the farmers widowed. In Taita-Taveta, a majority of the farmers were married (85.4%) and 1.6% of the respondents were separated (Table 3.1).

3.5.2 Cassava production characteristics for farmers in Kilifi and Taita-Taveta Counties

In Taita-Taveta, 80.2% had cassava grown in < 0.5 ha while in Kilifi county, only 55.9% had cassava in under 0.5 ha (Table 3.2). About 5.1% of the Kilifi respondents were not consuming cassava despite being growers while in Taita-Taveta County, only 2.4% of the respondents were not cassava consumers. In Kilifi, cowpea was the third most preferred plant intercrop (16.1%) with cassava after maize (62.6%) and pigeon pea (19.4%). However, in Taita-Taveta County, cowpea is rarely intercropped with cassava (1.7%). In Kilifi County, 52.4% of the farmers confirmed receiving some form of training regarding cassava production while In Taita-Taveta County, as high as 90.3% of the respondents had received some formal training on cassava production (Table 3.2).

Table 3. 1: Socio-demographic characteristics of cassava farmers in Kilifi and Taita-Taveta Counties

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Gender	Male	45.6[a]	56.9[a]
	Female	54.4[a]	42.3[a]
Age (years)	35 years	30.9[a]	13.0[a]
	36-50 years	32.4[a]	49.6[a]
	51-60 years)	14.0[a]	17.9[a]
	>60 years	22.8[a]	19.5[a]
Education	No formal education	25.7[a]	13.2[a]
	Primary education	59.6[a]	60.2[a]
	Secondary education	12.5[a]	17.1[a]
	Tertiary education	1.5[a]	9.8[a]
Household Head	Male	77.2[a]	82.1[a]
	Female	22.8[a]	17.9[a]
Occupation	Formal Employment	4.4[a]	1.8[a]
	Casual Employment	1.5[a]	1.0[a]
	Business Person	2.9[a]	1.6[a]
	Full Farmer	90.4[a]	92.4[a]
	Student	0.7[a]	3.2[a]
Marital Status	Single	5.9[a]	4.9[a]
	Married	83.7[a]	85.4[a]
	Widowed	10.4[a]	8.1[a]
	Separated	0.0 [a]	1.6[a]

Values with different superscripts along a row are significantly different under t-test

Table 3. 2 : Percentage of farmers in Kilifi and Taita-Taveta Counties involved in cassava production

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Cassava Farming	Yes	92.2^{a}	98.4^{a}
	No	7.8^{a}	1.6^{2}
Area under cassava	<0.5 acres	55.9^{a}	80.2^{b}
	0.5-1 acres	27.5^{a}	6.6^{b}
	1-2 acres	6.9^{a}	4.1^{a}
	>2acres	9.9^{a}	9.1^{a}
Previous Crop	Maize	62.6^{a}	21.5^{a}
	Cowpea	8.1^{a}	22.4^{a}
	Okra	10.1^{a}	0.9^{a}
	Pigeon Pea	2.0^{a}	1.9^{a}
	Pili Pili	1.0^{a}	0.0^{a}
	None	16.2^{a}	29.0^{a}
	Beans	0.0^{a}	5.6^{a}
	Banana	0.0^{a}	9.3^{a}
	Tomato	0.0^{a}	1.9^{a}
	Sweet Potato	0.0^{a}	7.5^{a}
Consumption	Yes	94.2^{a}	97.6^{a}
	No	5.8^{a}	2.4^{a}
Intercropping Cassava	Yes	94.9^{a}	96.6^{a}
	No	5.1^{a}	3.4^{a}
Crops for intercrop	Maize	41.9^{a}	54.8^{a}
	Cowpea	16.1^{a}	1.7^{a}
	Green grams	6.5^{a}	4.3^{a}
	Pigeon peas	19.4^{a}	22.6^{a}
	Beans	15.3^{a}	16.5^{a}
Received any training on cassava production	Yes	52.4^{a}	90.3^{b}
	No	47.6^{a}	8.7^{b}

Values with different superscripts along a row are significantly different under t-test

The harvesting characteristics of cassava roots (Table 3.3) indicates that whole farm harvesting of cassava roots is the most preferred method by the farmers in both Taita-Taveta (86.4%) and Kilifi (92.5) counties. The use of hoes as harvesting tool is the most preferred method in both Taita-Taveta (68.6%) and Kilifi (61.3%) counties. Farmers in Kilifi (33.1%) and Taita-Taveta (31.1%) preferred harvesting of the fresh cassava roots before 9am. Farmers in Kilifi considered the availability of markets (50%) as a major determinant of harvesting method and time of harvesting. In Taita-Taveta, maturity of cassava crop (55.9%) was the major factor taken into consideration with regards to harvesting time and method. In Taita-Taveta only 31% of the farmers would harvest the fresh cassava roots before physiological maturity unlike in Kilifi (54.7%). Harvesting for food is one of the major reasons cited by the farmers for harvesting before physiological maturity for both Kilifi (75.4%) and Taita-Taveta (76.7%). (Table 3.3)

Table 3. 3: Cassava roots harvesting practices for farmers in Kilifi and Taita-Taveta Counties

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Harvesting			86.4[a]
Cassava roots	Whole	92.5[a]	
	Piecemeal	7.5[a]	11.0[a]
Harvesting tools	Uprooting	22.6[a]	16.9[a]
	Jembe	61.3[a]	68.6[a]
	Panga	16.0[a]	13.6[a]
Harvesting time	5 – 9am	36.8[a]	33.1[a]
	10 – 12pm	36.8[a]	16.9[a]
	12 – 4pm	9.4[a]	18.6[a]
	>4pm	17.0[a]	18.6[a]
Time of harvesting Reason	market requirements	50[a]	27.1[a]
	labor availability	9.4[a]	14.4[a]
	temperatures	5.7[a]	1.7[a]
	Maturity	29.2[a]	55.9[a]
	consumption	5.7[a]	0.8[a]
Harvesting before Maturity	Yes	54.7[a]	31.8[a]
	No	45.3[a]	68.2[a]
Reason if yes	Money	24.6[a]	20.9[a]
	Food	75.4[a]	76.7[a]

Values with different superscripts along a row are significantly different under t-test

Table 3. 4: Cassava leaves harvesting practices for farmers in Kilifi and Taita-Taveta Counties

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Harvesting Cassava leaves	Whole	69.8[a]	72.1[a]
	Piecemeal	30.2[a]	26.1[a]
Harvesting tools	Uprooting	15.2[a]	24.1[a]
	Jembe	41.0[a]	57.4[a]
	Panga	2.9[a]	3.7[a]
	Hand	41.0[a]	13.9[a]
Harvesting time	5 - 9	28.8[a]	22.2[a]
	9 - 12 [	26.0[a]	37.0[a]
	12 - 4	18.3[a]	22.2[a]
	> 4 pm	7.7[a]	12.0[a]
	Anytime	19.2[a]	6.5[a]
time of harvesting reason	market requirements	29.8[a]	26.9[a]
	labor availability	18.3[a]	25.0[a]
	temperatures	7.7[a]	8.3[a]
	Maturity	27.9[a]	37.0[a]
	consumption	16.3[a]	1.9[a]

Values with different superscripts along a row are significantly different under t-test

In Kilifi County, 61% of the farmers sorted and graded their harvested cassava roots. The two most considered harvesting parameters were the size at 44.4% and levels of damages at 40.3 % (Table 3.5). About 57.1% of the respondents in Kilifi preferred immediate boiling of the damaged roots. Taita-Taveta county with only 34.2% of the farmers doing sorting and grading of the harvested cassava roots. Size and levels of damage were the two major factors considered for sorting and grading with a score of 40.9% and 36.4 %Kilifi and Taita-Taveta counties respectively. In Taita-Taveta majority of the respondents (69.1%) preferred immediate boiling of cassava. The main reason for sorting and grading was for price considerations in both the two counties with a percentage score of 45.8 and 43.2 for Kilifi and Taita-Taveta Counties respectively. (Table 3.5)

Table 3. 5: Distribution according to practice of farmers sorting and grading cassava in both Kilifi and Taita-Taveta Counties

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Sorting and grading			
	Yes	61.0[a]	34.2[b]
	No	39.0[a]	65.8[b]
Criteria for sorting	size	44.4[a]	40.9[a]
	color	8.3[a]	20.5[a]
	shape	6.9[a]	2.3[a]
	damage	40.3[a]	36.4[a]
Reasons for grading	specific markets	22.2[a]	20.5[a]
	price considerations	45.8[a]	43.2[a]
	storage	31.9[a]	27.3[a]
Utilization of damaged roots	immediate boiling	57.1[a]	69.1[a]
	immediate processing	23.8[a]	18.2[a]
	livestock feed	19.0[a]	4.5[a]

Values with different superscripts along a row are significantly different under t-test

About 69.2% of the Kilifi Farmers preserved Cassava while a larger percentage of the Taita-Taveta farmers did no preservation, with only 31% of the respondents doing preservation (Table 3.6). For both counties, the method of preservation was learnt from a fellow farmer with a percentage score of 59.5 and 55.8 in Kilifi and Taita-Taveta counties respectively. About 61.1% of the Kilifi farmers believed that on firm preservation method would last 3-5 days. While 60 % of the farmers who did saw dust preservation believed that the method would equally store the roots for 3-5 days. In Taita-Taveta, however, 58.5% of the farmers believed that underground method of preservation would store the roots for 3-5 days. (Table 3.6)

Table 3. 6 Preservation methods of Cassava in Kilifi and Taita-Taveta counties

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Cassava Preservation	Yes	69.2[a]	33.6[b]
	No	30.8[a]	66.4[a]
Information on preservation	farmer	59.5[a]	55.8[a]
	KALRO	18.9[a]	34.9[a]
	extension officer	8.1[a]	7.0[a]
	inherited	13.5[a]	2.3[a]
Garden Preservation time	1-2 days	27.8[a]	50.0[a]
	3-5 days	61.1[a]	32.6[a]
	5-7 days	11.1[a]	2.2[a]
Shade Preservation time	1-2 days	51.4[a]	32.5[a]
	3-5 days	35.1[a]	52.5[a]
	5-7 days	5.4[a]	10.0[a]
Underground Preservation time	1-2 days	46.0[a]	31.7[a]
	3-5 days	36.5[a]	58.5[a]
	5-7 days	17.5[a]	4.9[a]
Water Preservation time	1-2 days	56.5[a]	26.5[a]
	3-5 days	43.5[a]	58.8[a]
Sawdust preservation time	1-2 days	30.4[a]	20.0[a]
	3-5 days	60.9[a]	56.7[a]
	5-7 days	8.7[a]	10.0[a]

Values with different superscript along a row are significantly different under t-test

The farmers processing cassava roots into varied products, at least 2 in every 10 of the processors use chippers as a processing equipment in Kilifi County and for Taita-Taveta 1 in every 10 uses the chippers (Table 3.7). The use of knives for processing is the most preferred tool. Cleaning of the cassava roots before utilization was the most common driving reason for the farmers to process the roots. As a practice, fermentation is a technology adopted by most of the cassava roots processors with 2 of every 10 processing using the technology in Kilifi and Taita-Taveta counties. Most of the processing is done in open yards. (Table 3.7)

Table 3. 7 Processing equipment, treatment during processing, reason for processing and place of processing

Characteristics	Response	Kilifi Percentage	Taita-Taveta Percentage
Processing equipment	chippers	26.4[a]	18.2[a]
	graters	13.2[a]	19.3[a]
	solar dryers	17.6[a]	2.3[a]
	Pounding mortar	7.7[a]	12.5[a]
	Pangas	7.7[a]	5.7[a]
	Knives	22.0[a]	31.8[a]
	Grinding mill,	4.4[a]	10.2[a]
Treatment during processing	washing	34.4[a]	20.9[a]
	Fermenting	18.9[a]	22.1[a]
	Peeling	12.2[a]	29.1[a]
	Chipping	10.0[a]	8.1[a]
	Chopping	18.9[a]	17.4[a]
	Scrapping	3.3[a]	2.3[a]
Reason for processing	Cleaning	36.7[a]	41.4[a]
	Detoxify	12.7[a]	11.4[a]
	Reduce bulkiness	27.8[a]	12.9[a]
	Ease of further processing	12.7[a]	30.0[a]
	Better taste	5.1[a]	0.0[a]
Place for processing	Designated room	65.8[a]	53.5[a]
	Open place	34.2[a]	46.5[a]

Values with different superscripts along a row are significantly different under t-test

Cassava farmers are much aware of the varied cassava varieties and do prefer certain varieties for given products (Table 3.8). Tajirika remains the farmers most preferred variety. It was found that 33% of the respondents preferred the variety as being best for flour preparation. Income generation was the main reason why farmers processed the crops into varied products.

Table 3. 8 Varietal preference per cassava product for both Kilifi and Taita-Taveta Counties

Characteristics	Response	Grates	Crisps	Chips	Flour	Animal feed	Alcohol
Kilifi							
Variety	Tajirika	58.5	52.8	54.2	33.0	37.0	52.2
	Shibe	24.3	34.0	12.0	25.0	37.0	21.7
	Kibandameno	5.7	7.5	24.1	26.1	22.2	8.7
	Karembo	2.9	5.7	1.2	1.1	3.7	6.5
	Girikacha	2.9	0.0	4.8	10.2	0.0	6.5
	Kaleso	1.4	0.0	3.6	4.4	0.0	4.3
Reason	Income	50.0	54.7	48.2	40.5	39.6	54.0
	Subsistence	25.0	24.5	16.9	22.8	29.2	46.0
Taita-Taveta							
Variety	Tajirika	32.4	29.3	24.7	31.2	27.4	23.3
	Shibe	43.8	33.8	27.3	20.8	54.8	50.7
	Kibandameno	16.8	27.3	41.6	40.2	16.4	15.1
	Karembo	1.6	7.6	1.3	2.6	1.4	8.2
	Girikacha	1.6	1.0	2.6	1.3	0.0	1.4
	Kaleso	4.0	1.0	2.6	4.0	0.0	1.4
Reason	Income	53.4	55.3	61.0	64.9	50.0	52.1
	Subsistence	31.5	39.5	22.1	19.5	40.3	37.0

Cassava is processed majorly into Dried Chips and Flour (Table3.9). The farmers are keen to check on quality parameter of the products. In Kilifi county 3 in every 10 persons determine quality based on texture and 4 in every 10 persons prefer texture as a measure of quality. In Taita-Taveta county 47.1% of the respondents preferred the use of color as a parameter for quality determination of flour and about 60% preferred the use of color to determine quality of dried chips. Most of the products were stored in raised grounds in baskets while pests were the major cause of post-harvest loss in the two counties. (Table 3.9)

Table 3. 9 Processing characteristics of dried cassava chips and flour for respondents in Kilifi and Taita-Taveta Counties (% of respondents)

		Kilifi		Taita-Taveta	
characteristics	response	dried chips	flour	dried chips	Flour
frequency of processing	Daily	17.3	12.2	8.6	12.7
	weekly	50.7	51.2	14.3	15.5
	Monthly	18.7	29.3	15.7	28.2
	seasonal	9.3	4.9	57.1	40.8
	on demand	4.0	2.4	4.3	2.8
Quality parameters	color	31.6	27.2	58.1	47.1
	Texture	42.1	22.2	13.5	21.4
	Taste	22.4	43.2	17.6	17.1
	smell	3.9	7.4	8.1	14.3
	ropiness	0.0	0.0	2.7	0.0
reasons for preference	Easy to process	22.4	27.2	13.7	15.7
	High prices	21.1	22.2	19.2	27.1
	Consumption	55.3	43.2	58.9	55.7
	market	1.3	7.4	7.2	1.4
storage	On floor in house	39.7	23.4	27.3	40.9
	On a raised platform in house	57.1	71.9	56.8	52.3
	In a Granary	3.2	3.1	6.8	6.8
cause of loss during storage	Pests	34.5	39.0	32.1	14.8
	Caked	19.0	32.2	25.0	48.1
	Thieves	29.3	16.9	32.1	22.2
	broken	6.9	3.4	3.6	11.1
	rots	10.3	8.5	3.6	3.7

Cassava is a delicacy in most of the households at the Kenyan coast. A majority of the farmers prefer eating the food when cooked 31.1% and 34.8 % for both Kilifi and Taita-Taveta counties respectively (Table3.10).

Table 3. 10 Cassava consumption patterns and forms of consumption with incorporated foods

Characteristics	Response	Kilifi % of respondents	Taita-Taveta % of respondents
Form of consumption	Raw	15.6[a]	6.3[a]
	cooked	31.1[a]	34.8[a]
	boiled	25.6[a]	45.5[a]
	Fried	12.2[a]	8.0[a]
	roasted	15.6[a]	5.4[a]
Frequency of consumption	Daily	30.4[a]	8.0[a]
	weekly	56.5[a]	42.9[a]
	Monthly	8.7[a]	17.9[a]
	fortnight	4.4[a]	31.3[a]
Incorporate other foods	Cowpeas seeds	57.1[a]	46.2[a]
	Cowpeas leaves	27.5[a]	24.0[a]
	Pigeon peas seeds	11.0[a]	9.6[a]
	beans	4.4[a]	20.2[a]
Form of incorporation	Boiled	60.0[a]	29.8[b]
	Fried	33.3[a]	30.6[a]
	Both	2.2[a]	22.5[a]
Adverse effects after consumption of cassava	Yes	12.4[a]	5.8[a]
	No	83.1[a]	93.3[a]

Values with different superscripts along a row are significantly different under t-test

There is a significant positive correlation (P≤0.01) between growing cassava for income and receiving any form of training on cassava (Table 3.11). Therefore, the training the farmers received must have informed and changed their perception about the crop. In line with the farmers slogan of ‘Kilimo Biashara’, translated as ‘Agriculture as Business’ the correlation concurs with the farmers motto

Table 3. 11 The Chi Square Correlation between demographic and cassava production characteristics

	Gender	Household Head	Occupation	Education	Cassava Farming	Area Under Cassava	Cassava For Income	Intercropping Cassava	Information On Cassava
Gender	1								
Household Head	0.125*	1							
Occupation	0.112	-0.134*	1						
Education	-0.129*	0.021	-0.197**	1					
Cassava Farming	-0.010	0.113	-0.092	-0.058	1				
Area Under Cassava	-0.026	-0.059	0.052	-0.007	0.423**	1			
Cassava For Income	-0.041	-0.162*	0.112	0.008	-0.077	-0.048	1		
Intercroping Cassava	-0.095	-0.051	0.018	-0.011	-0.014	-0.036	-0.056	1	
Information On Cassava	-0.216**	-0.106	0.143*	0.112	0.063	-0.003	0.231**	-0.150*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

3.6 Discussion

3.6.1 Education status of the respondents

The percentage of respondents who had informal education was 25.7% and 13.2% for Kilifi and Taita-Taveta counties, respectively. The levels of eductation of respondents reported in this study were higher than the levels reported by Abong *et al.* (2016a) of 18. 7% for cassava processors who had non-formal education in Kilifi and Kwale counties. The study further reports an average of 59.9% of respondents as having attained primary education. The results are slightly above the levels reported for Kilifi county in a previous study by Abong et al. (2016) of 46.45%; the present study reports an increase in the level of access to education at primary levels. The levels of respondents who attained secondary education averaged 14.8%; the results are lower than the pooled average reported in studies done by Abong et al. (2016) when the score for ordinary and advanced secondary education are pooled together for the respondents from the coastal region. The levels of respondents who achieved tertiary in the current study averaged 1.5% and 17.1% for Kilifi and Taita-Taveta counties respectively. The percentage of respondents with tertiary education in the current study is in line with the increasing trend in access to primary and secondary education.

3.6.2 Cassava crop growth characteristics

The current study reports the average area under cassava production per farmer to be under 0.5 Ha, the majority of the farmers at the coastal region own small parcels of land that are put under production. Due to the long drought that occurred in the coastal region in the period 2015- 2017, there was massive loss of crops and crop production in the coastal region. The farmers lost much of the cassava cuttings to the drought. The area under cassava which is reported as to be majorly under 0.5 Ha is in agreement with the study done by Emily *et al.*(2016) in Migori County that reported the area under cassava production to be 1.04 acres per capita allocation. The levels are below 0.5 ha therefore land allocated to cassava farming is quite minimal. It is therefore necessary to increase capacity building by training the farmers on the new technologies (Abong et al., 2016). Cassava is a staple food to the people of the two counties and currently the crop serves as source of food and livelihood to the people (FAOSTAT, 2013). Despite the extremely harsh climatic conditions exhibited at the Kenyan coast, maize is still the farmer's preferred crop (table 2). Cassava is normally grown as an intercrop and also in farms that initially had other crops majorly maize (Table 2).

3.6.3 Cassava roots harvesting practices

Taita-Taveta and Kilifi counties as at 2016 were some of the counties that were marked by the Kenyan government to be food insecure. This explains the high percentage of farmers who harvested the crop before physiological maturity both for money and food. Moreover, as highlighted by Abong *et al.* (2016a), some of the leading reasons for wholesome harvesting (harvesting the entire cassava farm at once) of the cassava crops was the availability of the markets. According to Abdoulaye *et al.* (2014), knowledge of the farmers on the availability of the markets informed their choice of harvesting time. The commonly used tool for harvesting was the local Jembe (hoe). Following the low level of mechanization of the cassava harvesting coupled by the low level of technology adoption by the farmers reported by Abdoulaye *et al.* (2014) and Abong *et al.* (2016a) farmers still used the Jembe (hoe)to harvest their produce. When the farmers were probed further during the administration of the questionnaires, a section of the farmers preferred uprooting of the crops during the dry season. In such a period, the soils are averagely loose, and uprooting, especially for piecemeal harvesting becomes a preferred choice for the farmer.

3.6.4 Post-harvest handling of cassava roots

According to Table 3.4, while the farmers in Kilifi are aware of the need to do sorting and grading, the respondents from Taita-Taveta do not prefer sorting and grading of their produce. Price consideration (44.5%) was the major consideration by the farmers who preferred sorting and grading of their harvested cassava roots. To ensure better post-harvest handling of the crops, the farmers need to do proper sorting and grading of the produce. Sorting and grading of the product ensures that only the least damaged produce are channelled for preservation while the damaged cassava roots are either channelled for prompt consumption or put into feed production.

A majority of the cassava farmers received formal information regarding cassava farming. It is a common practice for the farmers to share information amongst themselves and thus the leading source of information as reported by the farmers in the current study was a farmer to farmer mode of communication. KALRO Mtwapa and the county government extension officers also provided some farming information to the farmers. About 7 in every 10 farmers received some training or formal information regarding cassava farming. The farmers are aware and utilize a range of preservation methods such as garden preservation, shade preservation, underground preservation, water preservation, and sawdust preservation. The preservation methods that the farmers have familiarized themselves with can only store the fresh cassava roots for a maximum of 7 days beyond which much of the produce are lost.

There are enormous losses of the produce harvested by the farmers due to poor post-harvest handling. Farmers normally experience pests and diseases in the field that affect the health of the plants and eventually, the yield realized by the farmers (Emmanuel et al., 2012). Moreover, as reported by Suryaningrat, Amilia and Choiron (2015) it becomes the role of each player in the cassava value chain to play its role efficiently to ensure a well-established cassava value chain.

The farmers play the primary role of plantation and supply of raw materials to the industry, however, in the Kenyan context, there is a missing link between the farmers and the market, and thus the farmers are forced to store much of their produce before getting access to the market. When such conditions arise, the farmers are often faced with the challenge of inadequate technologies to ensure better and efficient post-harvest storage of the produce.

3.6.5 Cassava processing storage and consumption patterns

Cassava being a staple food of the coastal region is often processed in open fields, 7 in every 10 processors prefer the open field in Kilifi County. Knives are the most preferred tool for processing while farmers can access community owned chippers to aid in processing of the crop. Cassava roots are often harvested with a lot of soil and thus as a processing procedure farmers prefer cleaning (washing) the roots, peeling then fermenting the roots to prolong their shelf life. The present study is in agreement with the findings by Abong *et al.*, (2016b) who reported about 16 % of the processors at the Kenyan coast cleaned (washed) their cassava.

Flour is the most produced cassava product followed by dried chips. Due to the low levels of capacity building farmers prefer simple and economical products. There is a current trend of eating quality foods which are nutritious and thus farmers are cautious when checking the quality of processed products. The present study reports color as the most utilized quality parameter by the farmers, as high as 58.1 and 47.1% for dried chips and roots respectively in Taita-Taveta County. The residents of Kilifi however preferred the use of texture (42.1% and 42%) as a quality check for the dried chips. Pest infestation (34%) is the major cause of loss of processed products (Ngo, 2013). The farmers in attempts to have nutritious meals have gone to the extent of incorporating other crops with the cassava roots to make nutritious meals famously known as Kimanga [1].

[1] Coastal name of a local delicacy of cassava and other crops incorporated meals.

3.6 Conclusion

Cassava crop is grown mostly in under 1 ha of land intercropped with legumes, cereals, fruits and vegetables. Cassava crop. Cassava products increase the plate options of the local farmers who utilize cassava crop while incorporating legumes to form delicious meals. The farmers do blend cassava flour with wheat flour for baking. There still exist major challenges in post-harvest handling and storage of the cassava roots. There is need for the research organisations, county governments and national government to create farmer awareness regarding production, agronomic practices and post-harvest handling of cassava crop.

CHAPTER FOUR

EFFECT OF PRE-PROCESSING TREATMENTS ON THE NUTRITIONAL COMPOSITION AND CYANIDE CONTENT OF THREE POPULAR CASSAVA VARIETIES, COWPEA LEAVES AND MILLET GROWN ALONG THE KENYAN COAST

4.1 Abstract

Cassava roots, millet and cowpea leaves have short storage life and thus the need for simple post-harvest handling and storage protocol to ensure prolonged availability in order to fully contribute to food and nutritional security which remains a major challenge within the tropical countries. The current study sought to investigate the effect of pre-treatment and processing on the nutritional composition of cassava roots, millet and cowpea leaves flours. The study used three popular cassava varieties grown along the Kenyan coast, cowpea leaves (M66) grown as vegetable and millet. The study used analytical techniques as guided by the AOAC standard methods, to determine the nutritional composition of the individual crops while subjecting them to pre-treatment processes (blanching, peeling, washing, drying, and fermentation) and optimizing for maximum nutrient composition. The cyanide content ranged 7.8-9.5, 3.4-5.0, and 2.2-2.8 ppb for raw, unfermented and fermented cassava flours, respectively. The carbohydrates content was in the range of 35-37, 81.73-83.49 and 70.28-71.20% for raw cowpea, cassava and millet respectively; the carbohydrate content for unfermented flours was in the range of 35.68-35.19, 66.07-83.49 and 66.07-68.89% for cowpea leaves, cassava roots and millet respectively; the carbohydrate content for the fermented flours was in the range of 29.06-28.01, 79.68-84.36 and 69.08-70.12% for cowpea leaves, cassava roots and millet, respectively. The protein content was in the range of 25.69-26.01, 1.2-18 and 11.1-13.3% for unfermented cowpea, cassava and millet

flours. Fermented flours protein content was in the range of 25.7-29.3%, 1.3-2.2%, 8.5-11.1% cowpea, and cassava and millet flours respectively. Iron and zinc content ranged 431.8-904.4 ug/kg, 100-130.54ug/kg; 798.2-789.7, 121-125; 658-823, 99.2-122.3, (ug/kg dwb) for raw, unfermented and fermented cowpea flours. Pre-treatment had significant effects ($P \leq 0.05$) on cyanide content and nutritional composition of each of the flours. Farmers and small scale processors should be trained to utilize simple processing techniques such as blanching and fermentation to improve nutritional quality and safety of cassava based products.

4.2 Introduction

Cassava roots are the third best source of starch after maize and rice (Wanapat & Kang, 2015). Globally the crop's utilization is on the rise due to the divergent product lines, including flour, dried chips, animal feed, and industrial starch (Abong et al., 2016). Following the trending global drive for promotion of the growth and utilization of indigenous crops as a means of dietary diversification and ensuring food security amongst the low income communities especially in the developing among third world countries, the growth and utilization of cassava is currently promoted with the aim of ensuring sufficient supply of carbohydrates and increased living standards of the farmers(Abong et al.,2016).

The crop, which is drought resistant, has been associated with regions that are afflicted with malnutrition (Wanapat & Kang, 2015). The crop is a highly valuable food crop for persons living in such zones. The cassava roots have a deficit of Sulfur-containing amino acids, and certain micronutrients are not optimally distributed. The promotion of the crop is hindered, especially among consumers who fear the high levels of cyanogenic glucosides associated with the roots (Olapade et al., 2014). Additionally, there is limited documentation of the effect of processing on the nutritional composition of the fresh cassava roots and the level of retention of nutrients. The study sought to device simple yet cost-effective and efficient techniques to reduce the levels of cyanogenic glucosides.

Cowpea leaves are one of the traditionally cherished crops for their high protein content (Okonya & Maass, 2014b). The indigenous vegetables are grown in small scale farms and even in urban Gardens. The leaves are a good source of protein and vitamins (Animasaun et al., 2015). The crops have been consumed cooked, fried and dried and even fermented to increase their utilization and this has gained a rising trend following the growing relevance of food composition for human nutrition (Gonçalves et al., 2016). Millet on the other hand, as a crop can survive under a varied range of soils and often does well even in areas of minimal rainfall and extreme temperatures (Chouhan, Gudadhe, Kumar, Kumawat, & Kumar, 2015). The crop, however, is known as a good source of minerals especially the limiting zinc and iron (Sharma, Saxena, & Riar, 2016). The crop is often milled into flour for consumption. To increase the availability of the nutrients of the millet flour fermentation has primarily been used as a processing technique (Fayemi & Ojokoh, 2014).

Cassava is deficient of minerals and vitamins; however, these are found in recommendable levels in cowpea leaves and millet. The nutritional contents that are available at relatively low amounts in cassava roots are available at significant levels in both cowpea leaves and millet, and thus the present study sought to create a blend of the flours of the three crops to come up with highly nutritious composite flours.

4.3 Materials and Methods

4.3.1 Study design illustrating sample collection and pre-processing treatments.

The study design (Figure 4.1.). The study involved three popular cassava varieties grown at the Kenyan coast. The three cassava varieties, millet and cowpea were subjected to pre-processing techniques of washing, peeling, drying, blanching, fermenting and milling into flours.

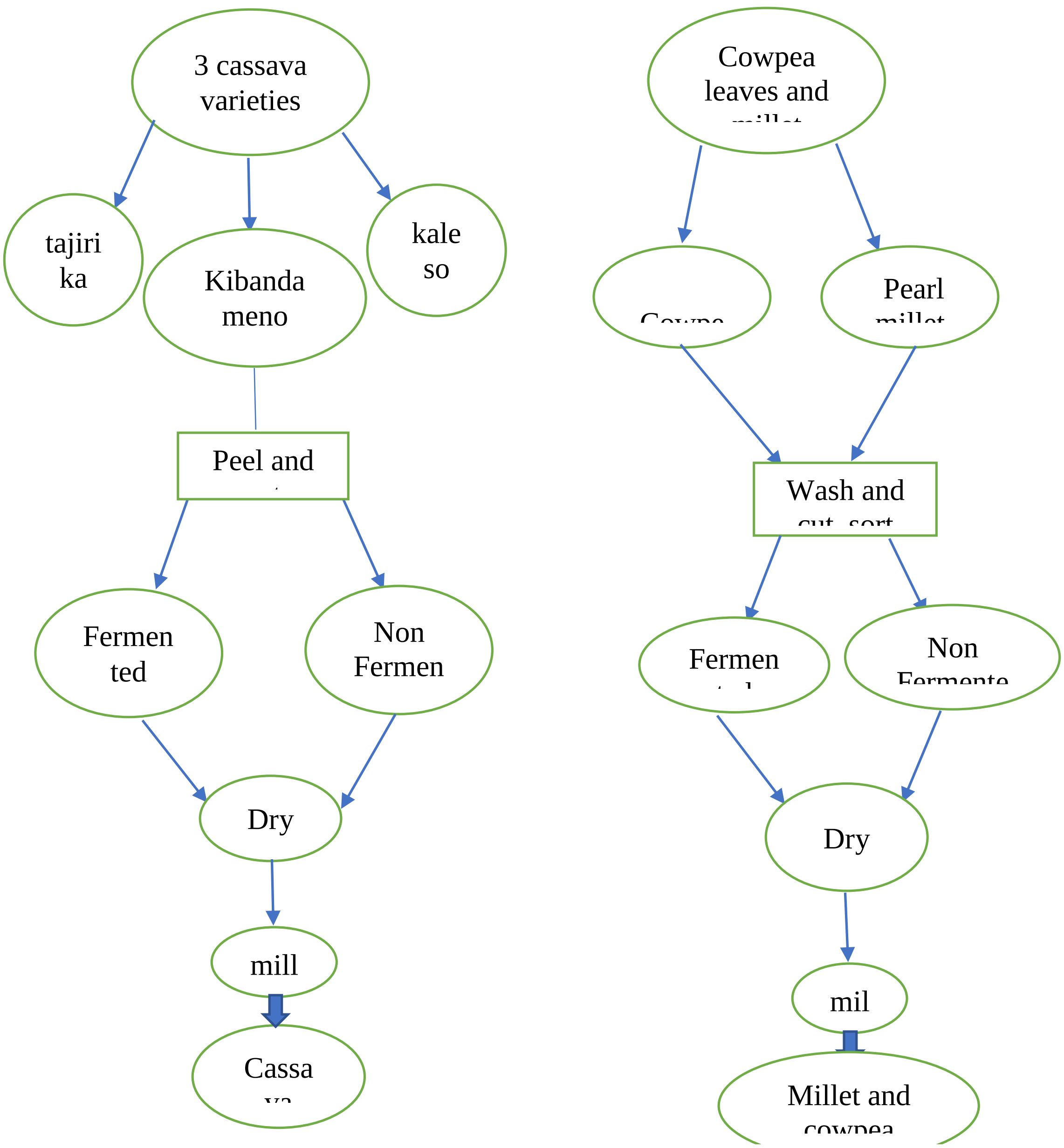

Figure 4. 1 sample collection and pre-processing treatments.

4.3.2 Acquisition of raw materials

The study utilized three cassava varieties that are typical of the Kenyan coast. In Focus Group Discussion in April 2018, the farmers majorly preferred Tajirika, Shibe, Kibandameno, and Kaleso .The sampling procedure targeted the farmers with preferred varieties. Through a systematic sampling procedure, samples were collected in 3 farms from two sub-counties in each of the counties for a particular variety. The sampled fresh roots were then stored in cooler boxes and transported overnight to the University of Nairobi Food Chemistry Laboratory for analysis. Millet is one of the cassava intercrops and thus readily available at the Kenyan Coast. Pearl millet grains were purchased in three different markets (Kongowea, Voi and Taveta) at the Kenyan coast and taken to the laboratory for analysis. Cowpea leaves, however, were grown at the University of Nairobi field station following standard agronomic practices and harvested at varied weeks from week two to week ten after planting to optimize for protein levels. The leaves were sampled on a weekly basis and taken to the laboratory for immediate analysis.

4.3.3 Sample preparation

4.3.3.1 Cassava roots preparation

The root samples were washed to remove any soils on the surface. The samples that were used to determine moisture content on a wet weight basis were never washed but peeled immediately. The washed cassava samples were then peeled and sliced into chips of size 30mm. The cassava chips were then oven dried at 60^{o}C for 24 hours before the dried chips were milled into flour. The milled flours for each variety were then mixed using a blender to ensure the samples were representative of sampled roots.

4.3.3.2 Preparation of cowpea leaves

The leaves that were harvested once every week were washed to remove any soil particles and reduced in size, approximately 3 mm. The samples were then blanched, and oven dried at 45^{o}C for 24 hours. The dried samples were then blended into fine powder for analysis.

4.3.3.3 Preparation of millet

The dry pearl millet samples were sorted to remove chaffs, the millet grains were then blended into flour. The milled pearl millet flour was then subjected to proximate analysis and eventually used to formulate composite flours.

4.3.3.4 Fermentation of composite flours

The varied composite flours were traditionally fermented by adding water to the flours in the ration of 3:2 to form a slurry and leaving to ferment for 2 days as per focus group discussion. The fermented flours were then dried and packaged.

4.3.4 Analytical methods

4.3.4.1 Moisture determination in an air oven

The moisture content of the raw samples and different flours were determined as per AOAC (2016) method number 934.01. About 5g of each sample was weighed into a dish, the dish and its contents were then put in an air oven maintained at 105^{o}C and left to dry for 24 hours. The samples were then cooled in a desiccator and weighed, the dish were then returned to the oven and dried until the moisture content variation was within 0.05%. The moisture content of the sample was then calculated as a percentage.

4.3.4.2. Determination of Ash

Ash content was determined as per AOAC (2016) Method number 923.03. About 2g of each sample was accurately weighed into a tared porcelain crucible and ashing started with low burning

Bunsen burner flame, the process was then continued in a muffle oven at 500 ^{o}C until a light grey ash of constant weight was obtained. The ash content of the sample was then calculated and expressed as a percentage.

4.3.4.3 Crude protein Determination

Crude protein was determined as per AOAC (2016) method number 992.15(39.1.16, approximately 0.5g of each sample was weighed in a nitrogen-free filter paper folded carefully and placed in a kjedahl flask together with anti-burning pumice, 1 kjedahl catalyst tablet and conc. Sulphuric acid was added and the mixture heated slowly in a fume cupboard until a clear solution was obtained. The boiling continued for 1 hour. The mixture was then cooled and a few drops of phenolphthalein added. A 400ml of conical flask containing 50ml of 0.1N HCl solution with some added methyl orange indicator was placed under the outlet of the distillation unit. 40% NaOH solution was added enough to change the colour of the solution and the mixture distilled until a drop of distillate did not react with Nessler's reagent placed in a test-tube. Back titration was then done with 0.1 N NaOH solution and the crude protein content of the sample calculated.

4.3.4.4 Crude fibre determination

Crude Fibre was determined According to AOAC (2016). Approximately 2g of the flours were weighed into a graduated 600ml of a beaker and a small amount of boiling water and 25ml of 2.04 sulphuric acid solution added. The volume of the solution was topped to 200ml and maintained while boiling for 30 minutes. The contents of the beaker were then filtered using a Buchner funnel slightly packed with glass wool and the residue washed. The residue together with the glass wool were then transferred into the beaker and a small amount of distilled water and 25ml of 1.73N KOH solution added, the volume was topped to 200ml with boiling distilled water and heated for 30 minutes. The solution was again filtered using a glass wool. The residue was transferred quantitatively into a porcelain dish and dried in an air oven set at 105 ^{o}C for 2 hours. The desiccator was then cooled and weighed. The dish content were then ignited at 550 ^{o}C before cooling and weighing. The crude fibre content of the samples were then calculated as percentage.

4.3.4.5 Crude fat determination

Crude fat content was determined as per AOAC (2016) method number 920.39. About 5g of the flours were weighed into an extraction thimble and covered with a cotton wool and placed in a sohxlet extractor. The tared flat bottomed flask with 200 ml of petroleum ether was then placed on a heating mantle and connected to the sohxlet extractor and the extraction let to run for 8 hours. The solvent was then evaporated in a rotary evaporator, the residue dried in an air oven set at 105^{o}C for 1 hour and the crude fat content expressed as a percentage.

4.3.4.6 Carbohydrates determination

Carbohydrates content was determined as per AOAC (2016) using the method of difference i.e 100% minus the total sum of fat, moisture content, crude fibre, Ash and proteins

4.3.4.7 Mineral content determination

The mineral content was determined as per AOAC (2016) by method number 985.27 for both zinc and iron. The mineral contents were read in an Atomic Absorption Spectrophotometer, buck Scientific 210 VGP, USA model.

4.3.4.8 Analysis of cyanide content in cassava roots

The cyanide content of the cassava roots was determined by distillation method as per AOAC (2016) raw cassava roots were peeled, washed, and dried. Fermented and milled samples were also evaluated. Ten grams of the samples were weighed and soaked in distilled water for 2 hours, and then subjected to the distillation process. Using 25 ml of 2.5% NaOH solution and collected to

200ml. the solution was then titrated with 0.02N silver Nitrate to a faint blue color and the cyanide content calculated as parts per billion (ppb).

4.3.4.9 Analysis of vitamins (A and C)

Approximately 2 g of each sample was extracted and stabilised with 25 mls of TCA (trichloro-acetic acid) then titrated using 0.001 N N-Bromosuciinamide and starch as indicator. Titre volume of N-Bromosuciinamide was then used in calculation to determine vitamin C using the formula V*C*(176/178)*100/weight of the sample = mg/100 g of Vitamin C, where V is titre volume, and C is Bromosuciinamide concentration (Abok et., 2016).

4.3.4.10 Blanching

The fresh cowpea leaves were divided into two batches. One of the batch was blanched using steam at 95°C for 5 minutes using the pilot plant blancher at the Department of Food Science, Nutrition and Technology, University of Nairobi. The blanched leaves were then dried to remove free water before being fermented.

4.4 Data Analysis

The data collected in the study were analysed using Genstat software for analysis of variances, means of the proximate composition of the samples to test for differences before and after processing to check the effect of processing on the nutritional composition of the samples.

4.5 Results

4.5.1 Cyanide content of three popular cassava varieties subjected to various pre-processing techniques

The cyanide content of the cassava roots was significantly different ($p<0.05$) among varieties and between pre-treatment processes. For the raw products, Kaleso had significantly higher ($P<0.05$) amounts of cyanide (9.65 ppb). After drying and milling, Tajirika had significantly ($P<0.05$)

higher amounts (5.0 ppb) of cyanide. The flours were subjected to fermentation process and after fermentation Tajirika had significantly higher (P<0.05) amounts (2.8ppb) of cyanide compared to kaleso (2.2 ppb) and kibandameno (2.3ppb).

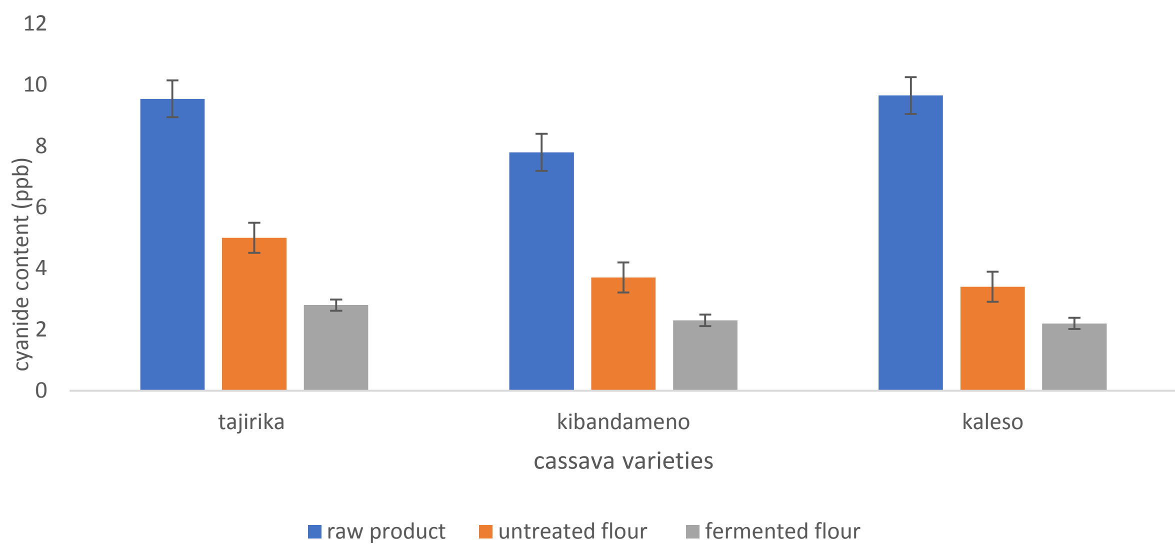

Figure 4. 2 Effect of pre-treatment processes on the cyanide content of cassava roots. The bars are standard error bars.

4.5.2 Proximate composition of raw, unfermented flours and fermented flours of cassava roots, cowpea leaves and pearl millet

The proximate composition of cassava roots, cowpea leaves, millet were significantly different (P<0.05) between the samples and between the various pre-treatment processes. The moisture content of raw cassava roots was in the range of 54-61%, the moisture content for the unfermented cassava flour was in the range of 6.76-10.28% and for the fermented cassava flour the moisture content was in the range of 8.30-8.75% (Table 4.1). The moisture content of pearl millet was significantly different when subjected under various treatments. The moisture content of pearl millet under varied treatments was in the range of 8.41 – 10.15%. The moisture content for cowpea leaves was high in the raw leaves 83.68%. The moisture content for the fermented cowpea leaves was significantly low at 6.5%. The crude fibre content of the samples was significantly different between the samples and between the pre-treatment processing. For the cassava samples, fermented Kaleso flour had significantly higher ($P<0.05$) fibre content 4.01% and detected in low amounts in raw Kibandameno 2.92%. The blanched fermented cowpea leaves had the highest fibre content 14.28% while the fibre content for cowpea leaves under pre-treatment processing was least in raw cowpea leaves 14.28%. The fibre content for millet was in the range of 4.13-4.13%. The ash content of the samples as highlighted in Table 4.2 shows that fermented Kaleso flour had significantly ($P<0.05$) higher ash content (2.60%). The ash content for cowpea was significantly ($p<0.05$) higher in raw cowpea leaves (11.08%) and low in dried fermented cowpea leaves 6.24%. The ash content for millet samples under varied pre-treatment processing was in the range of 1.66-1.85%.

The protein content was significantly different between the samples and between the pre-treatment processing. The protein content of Cassava roots was in the range of 1.15-2.21%. The fermented samples had significantly higher ($p<0.05$) protein content. The protein content was higher in fermented blanched cowpea leaves flour (29.31%) and lower in raw cowpea leaves (25.69%). The protein content for millet was in the range of 11.17-13.28%. The crude fat content was significantly different between the samples and between the various pre-treatment processing. The crude fat content was higher ($p<0.05$) in raw millet and blanched cowpea leaves (10.91%) and significantly lower in fermented Kaleso flour 1.31%. The crude fat for raw was 3.59%. For cowpea leaves dried fermented flour had the least amount (6.58%). The carbohydrates content of the samples was significantly different between the samples and between the treatments. The carbohydrates for the cassava roots was significantly higher ($p<0.05$) averaging 82.23%, the cowpea leaves carbohydrates was significantly low averaging 33.4% under varied pre-treatment processes. The energy content of the varied samples was significantly different between the samples and between treatments. The energy content was least in dried fermented cowpea leaves at 309 kcal/100g and significantly higher in unfermented Kibandameno flour 368 kcal/100g.

4.5.3 Effect of pre-treatment processing on the mineral and vitamin content of raw, unfermented flour and fermented flours of cowpea leaves, millet and cassava roots

The Iron content of the samples was significantly different between the samples and between the pre-processing treatments (Table 4.2). For the raw samples, Iron was significantly higher ($P \leq 0.05$) in Kaleso 99.30 mg/kg. For the unfermented cassava flour the iron content was significantly higher ($P \leq 0.05$) in Tajirika 39.50 mg/kg and for the fermented cassava flours the iron content was significantly higher in Tajirika 42.5 mg/kg (Table 4.2). The iron content was significantly higher in dried cowpea leaves 904.40 mg/kg. For millet samples raw millet had higher Iron content 137.20 mg/kg. The zinc content of the samples was significantly ($P \leq 0.05$) different between samples and between treatments. Raw cowpea leaves had significantly higher ($P \leq 0.05$) levels of zinc 130.54 (mg/kg) while the levels were significantly lower in fermented Kaleso flour 22.04 (mg/kg) (Table 4.2). There was no vitamin A detected in cassava roots samples and millet. Vitamin A in cowpea leaves samples was significantly ($P \leq 0.05$) different between samples and between treatments. Vitamin A was significantly higher in raw cowpea leaves ($P \leq 0.05$) 17.23 and significantly ($P \leq 0.05$) lower in dried cowpea leaves 6.36%. Vitamin C was significantly different between the samples and between pre-treatments processes. Unfermented Tajirika flour had significantly higher levels of vitamin C 30.14 while the levels of vitamin C was significantly lower ($P \leq 0.05$) in raw millet 9.87 (Table 4.2).

Table 4. 1 : Proximate composition of unfermented flours and fermented flours of cassava roots, cowpea leaves and pearl millet

Food crop	Treatment	Moisture content (%)	Crude fibre (%)	Ash content (%)	Protein Content (%)	Crude fat content (%)	Carbohydrates (%)	Energy (Kcal/100g)
Cassava Tajirika	Unfermented flour	8.37 ± 0.04^{c}	3.38 ± 0.02^{b}	1.85 ± 0.02^{c}	1.21 ± 0.02^{a}	3.59 ± 0.02^{e}	84.36 ± 0.17^{i}	355.90 ± 0.53^{h}
Tajirika	Fermented flour	10.28 ± 0.16^{d}	3.79 ± 0.34^{d}	1.81 ± 0.01^{bc}	1.33 ± 0.04^{a}	1.81 ± 0.08^{c}	82.70 ± 0.01^{g}	352.40 ± 0.54^{f}
Kibandameno	Unfermented flour	7.20 ± 0.03^{b}	2.92 ± 0.03^{a}	1.92 ± 0.02^{d}	1.15 ± 0.04^{a}	3.32 ± 0.02^{d}	83.49 ± 0.03^{g}	368.50 ± 0.08^{k}
Kibandameno	Fermented flour	8.30 ± 0.01^{c}	3.56 ± 0.01^{c}	2.05 ± 0.01^{e}	2.22 ± 0.06^{c}	1.61 ± 0.02^{b}	82.27 ± 0.05^{g}	352.40 ± 0.12^{f}
Kaleso	Unfermented flour	6.76 ± 0.07^{ab}	3.65 ± 0.02^{cd}	1.76 ± 0.04^{b}	1.79 ± 0.06^{b}	1.68 ± 0.05^{b}	79.68 ± 0.17^{e}	343.70 ± 0.68^{c}
Kaleso	Fermented Flour	8.75 ± 0.05^{c}	4.01 ± 0.01^{e}	2.60 ± 0.02^{f}	1.61 ± 0.15^{b}	1.31 ± 0.06^{a}	81.73 ± 0.18^{f}	345.10 ± 0.50^{e}
Cowpeas leaves	Raw	83.68 ± 0.65^{h}	11.60 ± 0.01^{h}	11.08 ± 0.07^{j}	25.69 ± 0.08^{f}	10.58 ± 0.05^{h}	29.06 ± 0.12^{a}	328.70 ± 0.23^{c}
Blanched leaves flour	blanched	83.56 ± 0.12^{h}	12.92 ± 0.02^{i}	10.08 ± 0.01^{i}	25.69 ± 0.08^{f}	10.91 ± 0.02^{i}	35.68 ± 0.05^{b}	343.70 ± 0.68^{d}
Dried leaves flour	dried	8.37 ± 0.11^{c}	11.60 ± 0.01^{h}	11.08 ± 0.07^{j}	25.69 ± 0.08^{f}	10.58 ± 0.05^{h}	29.06 ± 0.12^{a}	328.70 ± 0.23^{c}
Blanched fermented leaves	Fermented flour	6.69 ± 0.03^{ab}	13.54 ± 0.01^{j}	8.13 ± 0.01^{h}	29.31 ± 0.09^{h}	6.92 ± 0.06^{g}	37.71 ± 0.03^{c}	321.20 ± 0.48^{b}
Dried Fermented leaves flour	Fermented	6.50 ± 0.02^{a}	14.28 ± 0.02^{k}	6.24 ± 0.05^{g}	27.06 ± 0.02^{g}	6.58 ± 0.06^{g}	35.49 ± 0.05^{b}	309.50 ± 0.36^{a}
Pearl Millet	Unfermented flour	10.15 ± 0.03^{d}	4.73 ± 0.06^{g}	1.66 ± 0.02^{a}	13.28 ± 0.29^{e}	4.12 ± 0.02^{f}	66.07 ± 0.37^{c}	354.40 ± 0.27^{g}
	Fermented flour	8.41 ± 0.02^{c}	4.13 ± 0.06^{f}	1.85 ± 0.01^{c}	11.17 ± 0.05^{d}	4.15 ± 0.08^{f}	70.28 ± 0.08^{d}	363.20 ± 0.52^{j}
%CV		1.4	1.3	0.9	1.1	1.0	0.2	0.1
LSD		0.58	0.14	0.05	0.19	0.07	0.27	0.66
SE		0.29	0.07	0.03	0.09	0.04	0.13	0.32

Values with different superscript along a column are significantly different at $p<0.05$. Moisture is expressed on wet weight basis; protein, fibre, ash, fat, Carbohydrates are expressed on dry weight basis and energy is kcal/100g wet weight .

Table 4. 2: Effect of pre-treatment processing on the mineral and vitamin content of raw, unfermented flour and fermented flours of cowpea leaves, millet and cassava roots

Treatment	**Sample name**	Iron mg/kg	Zinc mg/kg	Vitamin A μg/kg	Vitamin C μg/kg
Raw	Kaleso	99.30±0.85^{h}	29.72±0.14^{c}	ND	14.77±0.03^{c}
Unfermented flour	Kaleso	23.30±0.30^{a}	25.04±0.07^{b}	ND	21.59±0.72^{g}
Fermented Flour	Kaleso	25.30±0.30^{b}	22.04±0.07^{a}	ND	19.22±0.04^{f}
Raw	Kibandameno	65.10±0.12^{g}	29.12±1.00^{c}	ND	11.36±0.04^{b}
Unfermented flour	Kibandameno	27.40±0.97^{c}	31.01±0.56^{e}	ND	20.87±0.74^{g}
Fermented flour	Kibandameno	29.10±0.62^{d}	29.34±0.53^{d}	ND	18.72±0.03^{f}
Raw	Tajirika	55.20±0.17^{f}	30.82±0.46^{e}	ND	10.29±0.08^{a}
Unfermented flour	Tajirika	39.50±0.66^{e}	39.43±0.48^{g}	ND	31.14±1.10^{j}
Fermented flour	Tajirika	42.50±0.50^{e}	36.43±0.48^{f}	ND	29.57±0.03^{i}
Raw	Blanched Cowpea	431.80±1.58^{l}	130.54±0.40^{k}	17.23±0.32^{e}	16.28±0.03^{d}
	cowpea	904.40±0.72^{p}	100.89±0.31^{k}	6.36±0.04^{a}	18.75±0.03^{f}
Unfermented flour	Blanched Cowpea	798.20±0.56^{n}	114.90±0.19^{l}	11.77±0.55^{d}	16.75±1.07^{d}
	Dried cowpea	798.20±0.56^{n}	114.90±0.19^{l}	11.77±0.55^{d}	16.75±1.07^{d}
Fermented	Blanched Cowpea	823.50±0.42^{o}	114.90±0.19^{l}	8.81±0.04^{b}	11.33±0.04^{b}
	Dried cowpea	658.50±0.51^{m}	121.95±0.05^{k}	10.10±0.30^{c}	13.28±0.03^{c}
Raw	Millet	137.20±0.72^{k}	79.15±0.61^{j}	ND	9.87±0.02^{a}
Unfermented	Millet	98.10±0.62^{h}	65.08±0.88^{h}	ND	29.25±0.48^{i}
fermented	Millet	105.70±0.09^{j}	69.08±0.13^{i}	ND	27.58±0.02^{h}
	%CV	0.2	0.7	5.8	2.8
	LSD	1.10	0.76	0.34	0.85
	SE	0.54	0.34	0.17	0.42

Values with a different superscripts along a column are significantly different at $p<0.05$. ND-not detected. Vitamins are measured in μg/kg and minerals in mg/kg.

4.6 Discussion

4.6.1 The effect of pre-treatment processing on the cyanide content of three popular cassava varieties.

The cyanide contents reported in the current study (Figure 4.1) are significantly below the maximum tolerated levels in consumable foods of 10ppm. Due to the lethality of cyanide, World Health Organisation, regional organisations such as East African community, Kenya Bureau Standards (Kebs) have set the standards to 10 mg kg-1(Abong et al., 2016). The highest level of cyanide according to this study was reported in Kaleso (9.65 ppb). The findings in this study are in agreement with study done by (Guédé, 2014) who recorded the cyanide content in fresh roots to be below 10ppb. Tajirika, an improved high yielding cassava variety, preferred for the high starch content and the high yield per plant that averages as high as 41kg per plant. Although the cyanide contents are at (9.54 ppb), peeling, washing, drying, and fermentation reduces the cyanide content of the roots by about 70% for the (Ismaila, Alakali, & Atume, 2018) Tajirika variety. The cyanide content for the native cassava variety (Kibandameno) for coastal Kenya is 7.79ppb and on processing by drying the levels change significantly ($p<0.05$) to 3.7ppb. The low levels of cyanide explain why the variety is preferred for consumption by the coastal Kenya residents. The cyanide content for the Kaleso variety was 9.65 ppb and after being solar dried for 24 hours, the cyanide content was significantly reduced ($p<0.05$) to 3.4 ppb. . The effect of processing on the cyanide content of cassava roots reported in this study are in agreement with (Ismaila et al., 2018) ,(Blanshard, Dahniya, Poulter, & Taylor, 1994) (Blanshard et al., 1994) and (Emmanuel et al., 2012) who reported that a combination of processing procedures that involved fermentation significantly reduced the levels of cyanide contents to within 10mg HCN per 100g maximum tolerated level in consumable food. Processing of cassava roots into flours significantly reduces the cyanide content (Muoki et al., 2015). Cyanide is one of the key toxicants in cassava roots and it occurs in both Sweet and bitter cassava varieties and acute cyanide toxicity can lead to death if not treated and thus the need to reduce the cyanide contents (Gacheru et al., 2015).

4.6.2 The effect of pre-treatment processes on the Nutritional composition of cowpea leaves, millet and cassava roots.

Drying as a pre-treatment process a significant effect on the moisture content of cassava roots, millet and cowpea leaves (Table 4.1). The moisture content of the cassava roots significantly dropped from an average 57.63% to an average 8.08%. The moisture content of cowpea leaves was significantly reduced from moisture content 83.6% to an average of 8.37%. Drying involves removal of water from the food samples. A reduction in the water content of the food samples reduces the water activity of the food and thus a significant reduction in the growth of micro-organism and thus inhibiting food spoilage due to micro-organism spoilage. The findings in the Emmanuel et al., (2012) that reported the moisture content to range from 6.96% to 9.66%. The moisture levels reported in the study showed no significant variation between the moisture content of the improved varieties (Kaleso and Tajirika) and the local cassava variety (Kibandameno). For better storage quality of flours, the moisture content should be below 12%, moisture content of above 12% would favour microbial growth and thus quick spoilage of the flours. The levels reported in the present study indicates that peeling, slicing, coupled with solar drying for 48 hours, serves as an efficient method of lowering the water content of cassava roots. The values were slightly lower than levels reported by Charles et al. (2005) and Shittu et al. (2007) who recorded an average of 11% and 16.5 respectively (Emmanuel et al., 2012). The effect of drying on cowpea leaves reported in the current study agree with the findings of Gerrano et al., (2015) who reported that dying of cowpea leaves reduces significantly the moisture content of cowpea leaves. The nutritional composition of cassava roots depends on the age, the geographical region, and the variety of the crops (FAOSTAT, 2011) and the part of the crop consumed. With the increased research on developing more nutritious varieties (the improved varieties), the nutritional composition of the root tubers are expected to increase due increased vitamin A (Abong et al., 2016).

Drying and fermentation significantly increases the crude fibre content of cassava roots, millet and cowpea leaves. The fibre content of cassava roots was significantly increased from an average of 3.32% to 3.78%. The fibre content of cowpea leaves was equally increased from 11.60% to 14.28%. The fibre content of millet was significantly reduced from 4.73% to 4.13%. Drying and fermentation concentrates the nutritional composition of the foods. The protein content of cowpea leaves was significantly increased through drying and fermentation. Fermentation was significantly increased from 25.69% to 29.31%. . The levels reported in this study are within the levels that were reported by Okonya and Maass (2014) of 28.02% -31.84%. The nutritional composition reported by Animasaun et al. (2015) has a lower protein level of 23.42%- 26.78 %, the levels reported in the present study however are relatively high, which can be attributed to the soils, variety of the crop and the age of harvesting. The present study optimized the use of cowpea leaves by pinching every week, the levels of protein were not significantly different between the plants harvested in the second week to the 8th week as the protein levels averaged approximately 28%, however from week nine the levels of protein significantly dropped to 26%. According the study done by Kulwa et al. (2015) one of the recommendations to ensure nutritional security is to improve on the feeding practices and nutrient content of complimentary meals through the incorporation of plant leaf protein in the protein deficient meals such as enriching cassava flour with both cowpea leaves and millet as source of protein and other micronutrients such as iron and zinc and vitamins. The crude fat content was significantly reduced from an average of 2.86% to an average 1.57%. The crude fat content of cowpea leaves was significantly reduced from 10.58 to 6.58%. The cowpea leaves had a significant level of protein (Oresegun et al., 2016) and (Wanapat & Kang, 2015) and (Salvador, Steenkamp, & McCrindle, 2014) all reported that the plant leaves could be a good source of protein in studies done on cassava leaves. The findings of the current study are in agreement with a study conducted by Kumar et al. (2016) reported the nutritional composition of 4 varieties of millet to range as follows, protein 6.8 -12.5%, fiber 2.4-15.6%, fat 0.5- 6.9%, energy 329-389 kcal/100g wet weight, carbohydrates 60.9-72.6% and moisture 11.9-13.1%. The findings in the present study report levels of fat, protein, carbohydrates, moisture, energy, and fiber as 4.1 %, 13.3%, 70.2%, 10.14%, 348.8 kcal/100 g wet weight, and 4.73 % respectively. The protein levels reported are quite low as compared to the levels reported by (Singh (2016) which ranged 7.3 %-12.5% and the protein levels reported by Kumar et al. (2016) who reported 6.8%-12.5% on average from 4 millet varieties.

Fermentation increased significantly ($P \leq 0.05$) the moisture content of the cassava varieties (Tajirika Kaleso and Kibandameno). The fibre content of the fermented products indicated a slight increase (Table 4.2). The protein content of cassava roots, millet, and cowpea leaves indicated an increase for the fermented products Fermentation increases the levels of protein by increasing the availability of protein (Ismaila et al., 2018); Wanapat and Kang, 2015) reported that fermentation of the cassava roots increases the protein levels by increasing the bioavailability of proteins. Apart from millet, the energy levels of the samples showed a decreasing trend. Processing of the fresh cassava roots, millet and cowpea leaves serves the key role of increasing the shelf-life of the roots, however, along with the processing, there is a significant drop in the energy (kcal/100 g), and this can be attributed to the significant drop of the levels of carbohydrates.

4.6.3 Effect of pre-treatment processes on mineral and vitamin content of cowpea leaves, millet and cassava roots.

Pre-treatment processing had significantly different effects on the mineral content of cowpea leaves, cassava roots and millet. The iron content of cassava roots was significantly reduced from as high as 99.30 to as low as 23.30. Drying and fermentation reduced the iron content of cowpea leaves from 904.4 to 658.5. The iron content of millet was equally significantly reduced. Drying and fermentation had a significant different effect on the zinc content between the sample and between treatments. The zinc content of cassava roots was significantly increased by a combination of drying and fermentation (Table 4.2). The levels of iron reported are in agreement with the levels reported by (Salvador, Steenkamp, and McCrindle, 2014) (Okonya & Maass, 2014b) on the protein and iron levels of cowpea leaves grown in local farms within Dodoma. The mineral and iron contents values were also within the range of values reported by (Singh, 2016) who reported that millets had a significant high amount of iron. The zinc levels in Tajirika an improved cassava variety significantly reduced with processing. From table 4.2 above the level of zinc generally reduces with processing for all the samples except for millet whose zinc levels increased. The level of vitamin C was significantly reduced due to pre-treatment processing. Vitamin A was not detected in cassava roots and millet.

4.7 Conclusion and Recommendation

Pre-treatment processing has significant effects on the nutritional composition of cassava roots, millet and cowpea leaves. Pre-treatment processing by peeling, washing, solar drying and fermentation reduces significantly the perishability of the foods while retaining much of the nutrients. Fermentation reduces HCN content to levels that are safe for human consumption. After processing the cowpea leaves have 28% protein and thus serves as a good source for blending a composite flour. Millet and cowpea leaves had significantly higher levels of zinc and iron and vitamin A and C.

Cassava varieties have different aroma on fermentation. The cassava flours are currently mixed with wheat for baking as a trending practice by the farmers and in line with the Kenyan policy on nutritional security by creating composite flours and using cassava flours for baking. Thus, it is of interest to the researchers to find out the potential baking properties of the varied cassava flours. Based on the high mineral content of the cassava roots, it is possible for the roots to accumulate high levels of heavy metals and thus it should be of interest to researchers to conduct further studies in this area.

CHAPTER FIVE

PHYSICO-CHEMICAL PROPERTIES, SENSORY AND KEEPING QUALITY OF CASSAVA COMPOSITE FLOURS ENRICHED WITH PROTEIN AND MINERALS FROM COWPEAS LEAVES AND MILLET

5.1 Abstract

Globally there is an increased demand for healthy, nutritious meals. The increased utilization of locally grown crops such as cassava roots which do well within the tropical countries ensure a healthier national balance of payment. The development of nutritious flour blends contributes towards two of the SDGs of creation of industries and achieving food and nutrition security. The current study used Nutrisurvey software in formulation of economical nutritious composite flour from cassava, cowpea leaves and millet while optimizing for protein, zinc and iron which are essential to the body especially in children and expectant women. Three flour formulations. GPF2 (20:50:30), GPF3 (10:50:40), GPF4(15:60:25) of cowpea leaves, cassava roots and millet respectively achieving more than 40% daily requirement of protein for the expectant woman were formulated and subjected to a sensory panel of 50 persons who scored for general acceptability, mouthfeel, texture and color against a standard commercial flour (GPF1) sold in the Kenyan market. The three formulated flours were subjected to accelerated shelf-life study based on physico-chemical properties and growth of yeast and molds. GPF1 and GPF2 had the highest color score of 5.18±1.35 and 5.18±1.48 ($p<0.05$) the score indicates a near equal acceptability of the flour based on color for both the standard porridge and the green porridge. GPF3 was the least accepted flour. GPF3 had the highest total aerobic count of 3.7 log cfu/g and the acid value of the flours ranged from as low as 1.84±0.01mg KOH/g for GPF2 at day zero and as high as 12.88±1.73 mg KOH/g at day six of accelerated shelf-life. The formulated flours had protein (8.0%) Fat (3.5%) carbohydrates (70%), Zinc (58.8) Iron (62.3) and vitamin C (24.4%).The current study recommends further studies on formulation of flours of legumes, root tubers and cereals.

5.2 Introduction

There is a global increase in the demand for highly nutritious foods which are economical and made from locally cultivated crops (Senevirathne, Rajasinghe, & Perera, 2016). The reduction of overreliance on wheat and wheat products ensures a reduction in the importation costs thus an increased balance of payments in the tropical countries (IITA, 2016). The crops that are highly promoted by the small scale farmers include tubers, roots, cereals and legumes which can be grown as intercrops (Senevirathne et al., 2016). Cassava roots are drought resistant crops that are a rich source of starch and one of the leading crops grown within the tropical countries as it currently feeds over 800 million people in the world (Abong et al., 2016). The Kenyan government in its BIG FOUR agenda has highlighted the promotion of cassava as a potential food security crop, an industrial game changer and a crop with diverse potential for creation of employment if the crop is fully exploited (Paul Odhiambo et al., 2018). Cassava starch production is one key step to ensuring an industrial impact of the crop (Mwizerwa et al., 2017). The crop is grown with other legumes such as cowpea leaves, pigeon pea, and beans as intercrops. Millet, maize and other cereals have been grown with cassava as intercrops. Thus in the realization of a prosperous Africa it becomes important to create nutritious meals which are economical to the farmers as the crops are naturally grown within the tropical country. Such a move shall ensure a massive reduction in the huge importation cost of wheat (Senevirathne et al., 2016).

There is a trending promotion of the use of composite flours which are protein enriched from locally grown tropical legume crops and other cereals crops (Muoki et al., 2015). The quality of the products that are made from such tuber-legume cereal combinations depend on the individual proportions of the primary constituents of the flours (Muoki et al., 2015). Millet as a crop is gaining fame amongst farmers who are cautious of healthy living due to its nutritional composition.

Millet is a good source of dietary fibre, calcium, phytates, protein and minerals (Adebiyi, Obadina, Adebo, & Kayitesi, 2017). The crop does well in the tropical countries and based on its nutritional composition has in the recent years been used as a substitute to wheat in the making of nutritious flours (Singh, 2016). Cowpea leaves is a major intercrop of Cassava and is greatly loved by the farmers and primary consumers of the crop for its high protein content, mineral content and vitamins. The crop is grown for both the grains and the leaves. The leaves are a good source of protein with approximately 28% of the crop being protein on dry weight basis (Okonya & Maass, 2014b). As a promotion of Agenda 4 and the Kenyan government policy to blend up to 10% of the flours with cassava, then development of a nutritious flour of tuber- legume and cereal origin becomes a timely technology (Chivenge et al., 2015). Such a promotion would ensure the drought prone areas which are often hit by hunger get nutritious meals as Cassava crop does well even in extremes of climate.

Composite flour technology includes the process of making various flours from tuber, legumes and cereals in proper proportions to make economic use of locally grown food products (Tharise, Julianti, & Nurminah, 2014). The aim of the current study was to promote the use of composite flours made from cassava roots, millet and cowpea leaves. The study further sought to develop and evaluate the optimal proportions of the primary raw materials for cassava-millet-cowpea leaves flour for the production of quality products. Despite the recent advances in formulation of the non-wheat flours from cereal-tuber-legume combinations there are no documented perfect end user combinations (Tharise et al., 2014). The present study therefore sought to document the physico-chemical properties, acceptability and keeping quality of protein and mineral enriched cassava-millet – cowpea leaves composite flours from selected cassava varieties grown at the Kenyan coast.

5.3 Materials and Methods

5.3.1 Preparation of cassava flours

Three cassava varieties (Kibandameno, Tajirika and Kaleso) were collected from farms in Taita-Taveta and Kilifi counties along the Kenyan coast. The samples were washed, peeled, washed, and oven dried at 60 ^{o}C for 24 hours. The dried chips were fermented then milled into fine flour for composite flour preparation.

5.3.2 Preparation of millet flours

Millet grains were collected from the farms in Kilifi counties, dried and sorted for best quality grains. The grains were milled into flour and the flour fermented and dried ready for use for the development of composite flour blends

5.3.3 Preparation of cowpea leaves flour.

Fresh cowpea leaves grown at the University of Nairobi field station farm while observing standard agronomic practices were harvested and fermented using sauerkraut technology. The fermented cowpea leaves were then blended into fine flour for use in making of composite flours.

5.3.4. Formulation of composite flours for sensory evaluation

The study used Nutrisurvey software developed by Dr. Jürgen in cooperation with Dr. Breind (WHO) in October 2014 for linear programming to generate the corresponding proportions of cassava roots, millet and cowpea leaves. The nutrients optimized were protein, fat, minerals level (zinc, Iron, Calcium) and Vitamins A and C. The optimization was done to ensure each formulation provides more than 40 % of the daily recommended intake of protein, fat, minerals (zinc, iron, calcium) and vitamin A and C. The three flour blends developed are shown in Table 5.1.

Table 5. 1 Flour formulations with optimization of protein, fat, zinc, iron and vitamin A and vitamin C.

Flour formulation	Cowpea leaves (%)	Cassava roots flour (%)	Millet flour (%)
GPF2	20	50	30
GPF3	10	50	40
GPF4	15	60	25

5.3.5 Analytical methods

5.3.5.1 Determination of proximate composition of the blended flours

The proximate composition of the varied composite flours was determine while following the procedures illustrated in chapter four under the analytical methods 4.3.4 page 48.

5.3.5.2 Accelerated shelf-life determination of composite flours

The accelerated shelf-life of the composite flours were determined as per AOAC (2016) method number 965.33 About 100 g of each sample flour was weighed and packaged in craft paper which currently is the standard storage container for commercial flours. The corresponding flour samples were then incubated at 55 degrees Celsius for 7 days and samples picked for microbial analysis (yeast and molds) and analysis peroxide value and acid value

5.3.5.3 Determination of moisture content of composite flours

The moisture content of the raw samples and different flours were determined as per AOAC (2016) method number 934.01. About 5g of each of the samples were weighed and put in an oven dryer at 80^{o}C for a period of 24 hours. The dried samples were later weighed and percentage weight loss determined. The percentage weight loss was expressed as the percentage moisture content of the respective flours.

5.3.5.4 Determination of the peroxide value

The peroxide value was determined as per AOAC (2016) method number 965.33. About 5g of the flour samples were weighed in a 300ml glass stoppered conical flask. 30 ml of the mixture of glacial acetic acid and chloroform in the ratio of 3:1 was added. 0.5 ml of saturated KI solution was added to the mixture and the solution stood in the dark for about 1 min while occasionally shaking. 30 ml of distilled water was added. The solution was titrated against 0.01N sodium Thiosulphate after addition of about 0.5 ml 0f 1% starch solution until the blue color disappeared.

PV= 1000(b-a) N/W in milliequivalents of peroxide oxygen per kg

a= ml of sodium thiosulphate for the blank

b= ml of sodium thiosulphate for the sample

w= weight of the sample

N= normality of the sodium thiosulphate solution.

5.3.5.5 Determination of composite flour Acid value

The acid value was determined as per AOAC method number 993.25. About 3g of the flour samples were weighed into 200ml conical flask. 40 ml of the solvent mixture of benzene and ethanol in the ratio of 1:2 were added and titrated with 0.1N alcoholic KOH solution against phenolphthalein indicator.

$$AV = \frac{-5.611\ (b-a)}{W}$$

Where

AV = Acid value

a= ml of alcoholic KOH used for blank

b = ml of alcoholic KOH used for the sample

w= weight of the sample.

5.3.5.5 Determination of microbial growth in the flours

Composite flour samples were held under accelerated conditions of 55^{o}C and samples taken for analysis at day zero all through to the fifth day. About 10g of each flour formulation was weighed into 90ml of diluent (0.85% sodium chloride solution) followed by serial dilutions to 10^-3. About 1ml of the dilutions were placed in petri dish and about 15 ml of acidified potato dextrose agar for yeast and molds while for total viable count 15 ml of plate count agar was added. The samples were then incubated at 37^{o}C for total viable count while for yeast and molds the oven temperatures were set at 30^{o}C. The incubation for total viable count was monitored at 24 hours while for yeast and mold the incubation time was 48 hours. Colony count was done using the colony counter and the results expressed by multiplying by the dilution factor of the plate counted. The procedures were followed in duplicate.

5.3.6 Sensory evaluation of the formulated flour blends

Porridge was prepared from the three composite flours by boiling litres of water in sufuria until it boils then adding a pre-mixed water and flour slurry (300g flour:1litre water) to the boiling water. The mixture was then stirred while heating till the desired cooking properties are achieved. Sugar was then added to taste before subjecting the flours to a sensory score Coded porridge samples made from the three composite flours formulations were presented for sensory evaluation to a panel of farmers who are primary consumers of cassava flours. The farmers were well trained on how to score for texture, color, taste and aroma of the varied porridge samples. The study used a 7 point hedonic scale scoring 1 for very much disliked, 2 for much disliked, 3 for disliked, 4 for liked and did not like, 5 for liked, 6 for liked a lot,7 for very much liked.

5.3.7 Data analysis

The data were analysed using SPSS statistical software version 21 for the analysis of variance (Anova) and the means were separated by the least significant difference at $p \leq 0.05$.

5.4 Results

5.4.1 Nutritional composition of formulated composite flours.

The nutritional composition of the varied composite flour formulations shown significant variations within the formulations ($p \leq 0.05$). GPF2 had the highest moisture content 9.84% while GPF1 had the least moisture content. The fibre content of the formulated flours averaged 5.3% with GPF1 having the highest amounts at 5.8%. The ash content of the three formulated flour had no significant variations. The flours had an average ash content of 3.3%. The formulated flours had significantly high levels of proteins. The protein content was however, not significantly different between the formulations. GPF1 had high levels of protein at 9%. The protein content was least in both formulation 2 and formulation 3 at 8%. The carbohydrate content of the three formulated flours were significantly different between the formulations. The carbohydrate content was high in formulation GPF2 (73.2%) and least in formulation GPF1 (70.3%). The formulated flours were however high in energy averaging at 352.6 kcal.

Table 5. 2 Proximate composition of formulated flour blends

proximate composition of formulated composite flours

Formulations	% Mositure	% Crude Fibre	% Crude Ash	% Protein	% Crude Fat	% Carbohydrates	Energy K cal/100g dwb
GPF1	8.8^{b}	5.8^{a}	3.5^{a}	9.0^{a}	3.5^{a}	69.4^{a}	351.1^{c}
GPF2	9.84^{a}	4.9^{c}	3.3^{a}	8.0^{a}	3.3^{a}	70.66^{b}	354.8^{a}
GPF3	8.87^{b}	5.3^{c}	3.2^{a}	8.0^{a}	3.2^{a}	72.43^{b}	351.9^{b}
Mean	9.2	5.3	3.3	8.33	3.3	70.83	352.6
LSD (P≤0.05)	0.05	0.1	0.6	1	0.3	0.6	0.5
CV (%)	0.2	0.6	8.2	5.4	4.3	0.4	0.1

5.4.2 The mineral and vitamin levels of the three formulated flour blends.

The minerals and vitamin levels of the formulated three flour blends had significantly different levels between the formulations. GPF2 had the highest level of Iron (63.3) while GPF3 had the least levels (52.3). The zinc levels of the three formulations averaged 63.0, the levels were, however, high in GPF2 (64.7) and least in GPF3 (60.1). The levels of Vitamin A was least in GPF2 (0.9) and high in GPF1 (1.7). The three flour blends had significantly different levels of Vitamin C. The vitamin C levels were high in GPF2 (25.3) and least in GPF1 (22.8)

Table 5. 3 Vitamins and mineral quantities in the formulated flour blends

Formulations	Minerals		Vitamins	
	Fe (mg/kg)	Zn (mg/kg)	Vitamin A(mg/kg)	Vitamin C(mg/kg)
GPF1	53.7^{b}	64.3^{a}	1.7^{a}	22.8^{c}
GPF2	63.3^{a}	64.7^{a}	0.9^{c}	25.3^{a}
GPF3	52.3^{c}	60.1^{b}	1.4^{b}	24.5^{b}
Mean	56.4	63.0	1.4	24.2
LSD (P≤0.05)	0.8	1.4	0.08	0.3
CV (%)	0.6	1.0	2.7	0.6

5.4.3 Sensory evaluation scores

The most appealing colour was in GPF1 and GPF2 with sensory scores of 5.18±1.35 and 5.18±1.48 ($p<0.05$) (table 5.2). There was no significant ($p>0.05$) difference in the sensory scores of the mouth feel. GPF3 was the least acceptable at $p<0.05$.

The three flour blends of cassava roots, millet and cowpea leaves (GPF2, GPF3, GPF4) were subjected to a seven scale hedonic score while comparing them with a locally retailed flour (GPF1). The sensory evaluation scores were significantly different between the samples and between each parameter of color, flavor, mouthfeel, texture and general acceptability. The color scores of the flours were significantly different ($P\leq0.05$). GPF2 had the highest color score of 5.18±1.48 while GPF4 had the least score 4.50±2.10. The flavour score of the different flours were significantly different ($P\leq0.05$) with GPF2 having the highest score 5.52±1.54 while GPF4 had the least score of 4.68±1.88. The texture scores of the four porridge were significantly different between the flours. The highest score was in GPF1 5.32±1.25 while GPF3 had the least scores 4.60±1.69. The general acceptability of the four flours GPF2 had the highest score 5.50±1.33

Table 5. 4 Sensory evaluation scores on a 7-point hedonic scale for porridge made from the composite flours

Samples	Colour	Flavour	Mouthfeel	Texture	General acceptability
GPF1	5.18 ± 1.35^{b}	5.04 ± 1.92^{ab}	5.08 ± 1.46^{a}	5.32 ± 1.25^{c}	5.16 ± 1.35^{ab}
GPF2	5.18 ± 1.48^{b}	5.52 ± 1.54^{b}	5.10 ± 1.67^{a}	5.10 ± 1.68^{bc}	5.50 ± 1.33^{b}
GPF3	4.46 ± 1.80^{a}	4.68 ± 1.88^{a}	4.60 ± 1.69^{a}	4.40 ± 1.57^{ab}	4.78 ± 1.60^{a}
GPF4	4.50 ± 2.10^{a}	4.72 ± 1.93^{ab}	4.42 ± 1.94^{a}	4.48 ± 1.56^{a}	4.86 ± 1.82^{ab}

Values with different superscript along a column are significantly different at (P≤0.05). . GPF1 – common retailed famila flour. GPF2 had 20:50:30, GPF3 10:50:40. GPF3 15:60:25. Of cowpea leaves, Cassava roots and millets percent composition respectively.

5.4.4 Microbial counts

GPF3 had the highest microbial counts (3.74 log cfu/g, (P≤0.05) during storage as shown in Figure 5.1 .The total viable counts decreased with storage in all the three samples as shown in.

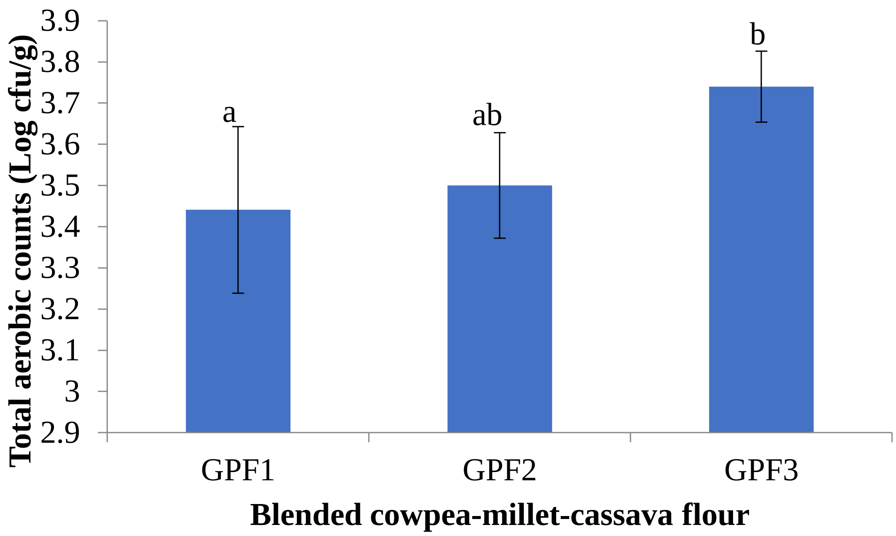

Figure 5.1: Total microbial (aerobic) counts of colony forming units per gram

Bars that are marked with different letters represent significant difference at (P≤0.05).

GPF1 – common retailed Famila flour. GPF2 had 20:50:30, GPF3 10:50:40. GPF3 15:60:25. Of cowpea leaves, Cassava roots and millets composition respectively. Figure 5.2 illustrates the total viable counts of over six storage months.

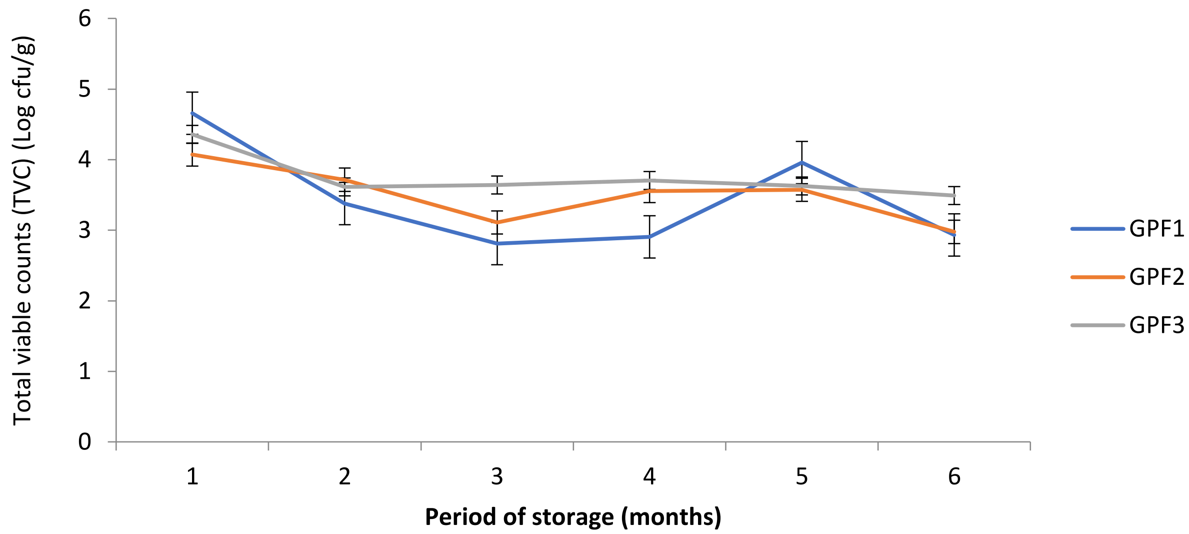

Figure 5 2 blended flour total aerobic counts with bars showing standard errors

5.5 The physico-chemical properties of the composite flours

5.5.1 The moisture content of the formulated composite flours

The moisture content of the 3 varied flour compositions at day one averaged at 11.23±0.16 and on storage, the flour moisture contents dropped significantly for the first two months before a steady rise from the third to the fifth month.The formulated flours were packed in craft paper and subjected to forced shelf-life analysis. The moisture content of the three flour blends had significantly different values between the samples and between the storage days. The moisture content of the flours averaged 11.23±0.16 and there were no significant variations. Major variations occurred at the third day of storage. GPF1 had the least moisture content while the levels were high in GPF2 2.34±0.03. The moisture content of the flours showed a decreasing trend before increasing from day 4 of storage to day 5.

Table 5. 5 Moisture content of the acceptable flours

Samples	Months						Average
	0	1	2	3	4	5	
	Moisture Content (%)						
GPF1	11.24±0.25[a]	3.54±0.03[a]	1.37±0.26[a]	3.62±0.04[a]	5.07±0.06[ab]	5.40±0.06[ab]	5.04±3.20[a]
GPF2	11.34±0.06[a]	3.68±0.37[a]	2.34±0.03[c]	3.61±0.04[a]	5.37±0.01[b]	5.63±0.02[b]	5.33±3.04[b]
GPF3	11.12±0.05[a]	3.48±0.01[a]	1.83±0.07[b]	3.51±0.01[a]	5.24±0.01[a]	5.33±0.01[a]	5.08±3.08[a]
Average	11.23±0.16[E]	3.56±0.19[B]	1.85±0.45[A]	3.58±0.06[B]	5.23±0.14[C]	5.45±0.14[D]	

Values with different lowercase letters along a column or uppercase letters across the row are significantly different at (P≤0.05).

Table 5. 6 Acid value of the acceptable composite formulated flours

Acid value							
Months							
Sample	0	1	2	3	4	5	average
GPF1	2.65± 0.06[c]	4.57± 0.06[c]	5.08± 0.05[b]	5.62± 0.01[a]	22.43 ±0.01[a]	23.19 ±0.07[a]	10.59± 9.08[a]
GPF2	1.84± 0.01[a]	3.92± 0.02[a]	4.16± 0.07[a]	7.45± 0.05[c]	29.63 ±0.42[c]	30.27 ±0.22[c]	12.88± 12.73[c]
GPF3	2.09± 0.08[b]	4.08± 0.06[b]	5.12± 0.02[b]	6.85± 0.09[b]	26.45 ±0.15[b]	27.90 ±0.04[b]	12.08± 11.25[b]
Average	2.19± 0.37[A]	4.19± 0.31[B]	4.79± 0.48[C]	6.64± 0.83[D]	26.17 ±3.24[E]	27.12 ±3.23[F]	

Values with different lowercase letters along a column or uppercase letters across the row are significantly different at (P≤0.05).

5.6 Discussion

5.6.1 Nutritional composition of the flour blends

The cassava roots- cowpea leaves and millets flour blends formulated in the current study have a high protein content which is above 9.0g in 100g as exhibited in GPF2, while GPF3 and GPF4 with the least protein content of 8.0g. Protein is deficient in pure cassava flours as the cassava roots are low in protein, however, the addition of cowpea leaves with high protein content of above

25% on dry weight basis increase the protein content of the formulated flours (Okonya & Maass, 2014a). . The blended flours are high in crude fat giving up to 3.5g fat in 100g, the levels of fat is due to the high fat content in cowpea leaves and pearl millet which are used as blends of the flour. (Glycine, 2014). The flours which majorly uses cassava roots as the major raw material has over 70.1g carbohydrates content and thus serves to supply 100 % of the total energy requirement as given in the nutrisurvey output (appendix). The blended cassava roots-millet-cowpea leaves composite flour on average gives 76% of the total protein required in a day if one consumes 100g of the flour (appendix). The nutritious flour blends provide 89% of the daily required magnesium and on average above 40 % of the daily required iron and zinc minerals. The minerals are important for normal human growth and in most cases given to expectant women as supplements (Bibiana, Grace, & Julius, 2014)and thus the provision of such minerals from legume, root tuber and cereal blended flour becomes a major contribution in meeting the expectant woman's nutritional requirements.

5.6.2 Sensory evaluation scores for the blended flours

Three varied formulations of the cassava-millet-cowpea leaves flours were subjected to a team trained sensory panellists (n=50, 30 females and 20 males). The panellist comprised of consumers who were familiar with cassava flours (Kayitesi, Duodu, Minnaar, & de Kock, 2010) and were willing to consume cassava based porridge. The general acceptability of the varied porridge flours was a function of the texture, color, flavor and texture of the various flour compositions. The most appealing color to the panelist was the GPF1 and GPF2 (5.18±1.35 and 5.18±1.48 ($p<0.05$). GPF1 porridge that was a common retailed flour and the farmers were already consuming the flours. The GPF2 had a perfect color blend of the individual composite flours and thus was the most acceptable by the farmers. Despite, the varied composite flours having no significant variations in terms of the mouth feel, the texture of the flours were significantly varied. The GPF2 flour had the highest score (5.52±1.54) and was the most generally accepted flour (5.50±1.33). The GPF2 flour had the highest protein content (7.3%) and thus on cooking it developed flavors (Muoki et al., 2015)that masked the cowpea leaves after taste. The combination of 20:50:30 % of cowpea leaves, Cassava roots and Millet gave an optimized nutrient composition of the flour and the best combination for general consumer acceptability according to the current study. Cereals are important sources of dietary fibre, minerals and phytochemicals and thus the inclusion of millet in the composite flour blends improves on nutrition (Lansakara et al., 2016). Nutrition plays a vital role in the physical and mental well-being of humans (Lansakara et al., 2016).

5.6.3 The physico-chemical properties of the varied flour blends

The varied flour combinations exhibited significant variations in moisture contents after 4^{th} and 5^{th} month. The flours therefore can be stored in craft paper for a period of 3 months without significant variations in the moisture content provided the flours are kept in dry conditions with minimal relative humidity.(Olapade et al., 2014)

There was no peroxide value detected in the 3 varied composition of flours over the storage duration. Therefore, the would be minimal or no spoilage due to fat increase in the flours (Vanhanen & Savage, 2006). The moisture content of the flours varied significantly at day zero and at day 1 averaging 11.23±0.16 and 3.56±0.19. the moisture content of the flours showed a steady increase but were still low ranging from 5.33±0.01 and 5.63±0.02 at five months and thus the cassava- millet- cowpea leaves flours can be stored in craft paper for five months without major alterations in the quality of the flours.

The total viable count of all the flour formulation according to this current study indicated a fall in the TVC for all the flour formulations. This can be attributed to thermal shock to the micro-organism and the significant drop in water content of the samples from 11.23±0.16 to 3.56±0.19. The drop in moisture content led to a significant reduction in water activity and thus the evident drop in total counts. The stable steady rise in total colony count is due to the adaptation of the micro-organisms.

5.7 Conclusions and Recommendations

Cassava roots-millet- cowpea leaves flour is a nutritious flour with as high as 9.0 % protein content and generally accepted by the native residents of Kenyan coast for utilization. The porridge if made following the hurdle technology indicated in the current study of ensuring minimal growth of yeast and molds during the drying process, and monitoring the flours through the milling process can serve as a part of solution to the malnutrition that is often is exhibited at the Kenyan coast, especially in Taita-Taveta and Kilifi counties. The flours do have a longer shelf-life of more than 6 months and thus can be kept in store for utilization during the periods of scarcity in supply.

Flours made from legumes, root tubers and cereals are highly recommended for formulations to ensure people are feed with a range of nutritionally essential minerals. The cassava roots-cowpea-leaves millet composite flour mixed in the ration of 20:50:30 of cowpea leaves, Cassava and millet respectively is, according to this study, recommended for commercialization as it is highly nutritious and preferred by the consumers. Further studies should be conducted to blend more of the cereals, legumes and root tubers to form highly nutritious flours that are rich in zinc and Iron.

CHAPTER SIX

GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

6.1 General discussions

Food and nutritional insecurity is a major challenge within the tropical countries. Kenya is 75% arid and semi-arid and thus the promotion of cassava farming serves to contribute towards a food and nutritional secure country while putting the ASAL areas into productivity. The cassava roots is grown intercropped with other legumes and cereals such as cowpea leaves, millet, pigeon peas, and beans. Cassava roots, cowpea leaves and millet have short post-harvest life and thus the need for processing to ensure increased availability for use while minimizing post-harvest losses. The processing of cassava roots and cowpea leaves by peeling, washing, blanching, drying, fermenting and milling greatly reduces the water activity of the crops and thus reducing the rate of spoilage. The cyanide content of the roots gets reduced by more than 40% when subjected to such processes. The processed cowpea leaves, millet and cassava roots are blended in varied ratios to develop a highly nutritious composite flour that is good for general family use. The cassava millet and cowpea leaves flour is rich in protein, zinc, iron and vitamins A and C. The flour can store for more than 5 months and thus minimizing post-harvest losses by increasing the diversification of use of the cassava roots and cowpea leaves.

6.2 General conclusions

Cassava roots is utilized at the Kenyan coast as dried chips, crisps, boiled roots and flour as the popular utilization channels. Cassava is grown majorly in small scale farms (less than 1Ha).

Fermented dried cowpea leaves are high in protein (28.1% on dwb). Cassava roots are a rich source of carbohydrates and millet a good source of fat. The three crops are mixed in proportions to form cassava roots-millet-cowpea leaves nutritious flour. The flour which is highly nutritious can be commercialized and availed to the farmers for utilization during the periods of scarce. The dried cassava chips have a longer storage life due to the highly reduced water activity while cowpea leave and millet are readily available in the markets and can equally be grown as cassava roots intercrops.

Processing washing, peeling, drying, and fermentation reduces cyanide content by about 44% to not more than 2.8 ppb which is way below the recommended 10ppb per 60kg body weight. Cassava roots-millet-cowpea leaves is a highly nutritious flour rich in energy, protein, carbohydrates, calcium , iron zinc and should be the choice source of flour for promotion in the drive to achieve nutrition and food security with the tropical countries since it uses locally grown cereals, legumes and roots.

Pre-treatment processing reduces the moisture content of cassava, cowpea leaves and millet. A reduction in the water content reduces water activity and thus inhibiting growth of micro-organism. The rate of spoilage is significantly reduced and thus the formulated composite flours can store for more than 5 months.

6.2 General Recommendations

There is an increasing demand for nutritious food. The development of legumes, cereal and root crop flour formulations contributes towards meeting such a demand and thus there is need to further research on such nutritious flour formulations. The processing of cassava roots, millet and cowpea leaves increases the utilization of the crops. The formulated flours needs to be commercialized as this would increase the economic value of the crops which translates to better living standards of the farmers and equally creation of job opportunity to the women and youth through commercialization of composite flours.

The formulated flours affirms the Kenyan government policy on inclusion of cassava up-to 10% in retailed flours. The current study informs that cassava can be used up-to 50% in formulation of porridge flours. The cassava flour can equally be used into the baking and thus an extension of the cassava crop diversification.

REFERENCES

Abdoulaye, T. ., Abass, A. ., Maziya-Dixon, B. ., Tarawali, G. ., Okechukwu, R. ., Rusike, J. ., … Ayedun, B. . (2014). Awareness and adoption of improved cassava varieties and processing technologies in Nigeria. *Journal of Development and Agricultural Economics*, *6*(2), 67–75. https://doi.org/10.5897/jdae2013.006

Abdullahi, M. S. A. . (2014). Comparative Study of Different Processing Methods for the Reduction of Cyanide from Bitter Cassava Flour. *CSJ*, *5*(1), 1–7.

Abok, E., Ooko, G., & Okoth, M. (2016). Cassava chips quality as influenced by cultivar, blanching time and slice thickness. *African Journal of Food, Agriculture, Nutrition and Development*, *16*(4), 11457–11476. https://doi.org/10.18697/ajfand.76.16855

Abong, George;, Shibairo, S., Wanjekeche, E., Ogendo, J., Wambua, T., Lamuka, P., … Masha, C. (2016a). Post-Harvest Practices, Constraints and Opportunities Along Cassava Value Chain in Kenya. *Current Research in Nutrition and Food Science Journal*, *4*(2), 114–126. https://doi.org/10.12944/crnfsj.4.2.05

Abong, George;, Shibairo, S., Wanjekeche, E., Ogendo, J., Wambua, T., Lamuka, P., … Masha, C. (2016b). Post-Harvest Practices, Constraints and Opportunities Along Cassava Value Chain in Kenya. *Current Research in Nutrition and Food Science Journal*, *4*(2), 114–126. https://doi.org/10.12944/CRNFSJ.4.2.05

Abong, GO, Shibairo, S., Okoth, M., Lamuka, P., Katama, C., & Ouma, J. (2016). Quality and safety characteristics of cassava crisps sold in urban Kenya. *African Crop Science Journal*, *24*(1), 89. https://doi.org/10.4314/acsj.v24i1.9s

Adebiyi, J. A., Obadina, A. O., Adebo, O. A., & Kayitesi, E. (2017). Comparison of nutritional quality and sensory acceptability of biscuits obtained from native, fermented, and malted pearl millet (Pennisetum glaucum) flour. *Food Chemistry*, *232*, 210–217. https://doi.org/10.1016/j.foodchem.2017.04.020

Animasaun, D. A., Oyedeji, S., Mustapha, O. T., & Azeez, M. A. (2015). Genetic Variability Study Among Ten Cultivars of Cowpea (Vigna unguiculata L. Walp) Using Morpho-agronomic Traits and Nutritional Composition. *Journal of Agricultural Sciences*, *10*(2), 119. https://doi.org/10.4038/jas.v10i2.8057

AOAC. (2016). *Nutritional Proximate Analysis : Moisture, Protein, Ash, Fibre*.

Awolu, O. O. (2017). Optimization of the functional characteristics, pasting and rheological properties of pearl millet-based composite flour. *Heliyon*, *3*(2), e00240. https://doi.org/10.1016/j.heliyon.2017.e00240

Bibiana, I., Grace, N., & Julius, A. (2014). *Quality Evaluation of Composite Bread Produced from Wheat , Maize and Orange Fleshed Sweet Potato Flours*. *2*(4), 109–115. https://doi.org/10.12691/ajfst-2-4-1

Blanshard, A. F. J., Dahniya, M. T., Poulter, N. H., & Taylor, A. J. (1994). Fermentation of cassava into foofoo: Effect of time and temperature on processing and storage quality. *Journal of the Science of Food and Agriculture*, *66*(4), 485–492. https://doi.org/10.1002/jsfa.2740660410

Burns, A. E., Bradbury, J. H., Cavagnaro, T. R., & Gleadow, R. M. (2012). Total cyanide content of cassava food products in Australia. *Journal of Food Composition and Analysis*, *25*(1), 79–82. https://doi.org/10.1016/j.jfca.2011.06.005

Chandrasekara, A., & Josheph Kumar, T. (2016). Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits. *International Journal of Food Science*, *2016*. https://doi.org/10.1155/2016/3631647

Chivenge, P., Mabhaudhi, T., Modi, A. T., & Mafongoya, P. (2015). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, *12*(6), 5685–5711. https://doi.org/10.3390/ijerph120605685

Chouhan, M., Gudadhe, N. N., Kumar, D., Kumawat, A. K., & Kumar, R. (2015). *Transplanting Dates and Nitrogen Levels Influences on Growth , Yield Attributes , and Yield of Summer Pearl*. *10*(3), 1295–1298.

Emily, A. M., Joshua, O. O., Midatharahally, N. M., Rory, H., Richard, M. S. M., & Peter, F. A. (2016). Occurrence and estimated losses caused by cassava viruses in Migori County, Kenya. *African Journal of Agricultural Research*, *11*(24), 2064–2074. https://doi.org/10.5897/ajar2016.10786

Emmanuel, O. A., Clement, A., Agnes, S. B., Chiwona-Karltun, L., & Drinah, B. N. (2012). Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (Manihot esculenta crantz) varieties. *International Food Research Journal*, *19*(1), 175–181.

FAO, IFAD, UNICEF, WFP, & WHO. (2017). Building Resilience for Peace and Food Security. In *The State of Food Security and Nutrition in the World*. https://doi.org/10.1080/15226514.2012.751351

Fayemi, O. E., & Ojokoh, A. O. (2014). The effect of different fermentation techniques on the nutritional quality of the cassava product (FUFU). *Journal of Food Processing and Preservation*, *38*(1), 183–192. https://doi.org/10.1111/j.1745-4549.2012.00763.x

Gacheru, P., Abong, G., Okoth, M., Lamuka, P., Shibairo, S., & Katama, C. (2015). Cyanogenic Content, Aflatoxin Level and Quality of Dried Cassava Chips and Flour Sold in Nairobi and Coastal Regions of Kenya. *Current Research in Nutrition and Food Science Journal*, *3*(3), 197–206. https://doi.org/10.12944/crnfsj.3.3.03

Gerrano, A. S., Adebola, P. O., van Rensburg, W. S. J., & Venter, S. L. (2015). Genetic variability and heritability estimates of nutritional composition in the leaves of selected cowpea genotypes [Vigna unguiculata (L.) Walp.]. *HortScience*, *50*(10), 1435–1440.

Glycine, S. (2014). *Effect of Fermentation on Nutrient and Anti-nutrient Composition of Millet (*. *8*(8), 668–675.

Gonçalves, A., Goufo, P., Barros, A., Domínguez-Perles, R., Trindade, H., Rosa, E. A. S., … Rodrigues, M. (2016). Cowpea (Vigna unguiculata L. Walp), a renewed multipurpose crop for a more sustainable agri-food system: Nutritional advantages and constraints. *Journal of the Science of Food and Agriculture*, *96*(9), 2941–2951. https://doi.org/10.1002/jsfa.7644

Guédé, S. S. (2014). Assessment of Cyanide Content in Cassava (Manihot esculenta Crantz) Varieties and Derived Products from Senegal. *International Journal of Nutrition and Food Sciences*, *2*(5), 225. https://doi.org/10.11648/j.ijnfs.20130205.12

Gupta, A., & Verma, J. P. (2015). Sustainable bio-ethanol production from agro-residues: A review. *Renewable and Sustainable Energy Reviews*, *41*, 550–567. https://doi.org/10.1016/j.rser.2014.08.032

IITA. (2016). *Annual report 11-16*.

Institute, K. A. R. (n.d.). New Cassava varieties for Coastal Kenya. *KARI Information Brochure Series / 58 /2008*.

Ismaila, A. R., Alakali, J. S., & Atume, T. G. (2018). Effect of Local Processing Techniques on the Nutrients and Anti-Nutrients Content of Bitter Cassava (Manihot Esculenta Crantz). *American Journal of Food Science and Technology*, *6*(3), 92–97. https://doi.org/10.12691/ajfst-6-3-1

Israel, G. D. (2003). Strategies for Determining Sample Size. *University of Florida IFAS Extension*, *5*. https://doi.org/10.1016/j.envpol.2016.06.04

Kayitesi, E., Duodu, K. G., Minnaar, A., & de Kock, H. L. (2010). Sensory quality of marama/sorghum composite porridges. *Journal of the Science of Food and Agriculture*, *90*(12), 2124–2132. https://doi.org/10.1002/jsfa.4061

Koskei, Felix; Kariuki, Sicily; Ntiba, Micheni; Sigor, F. (n.d.). *Household Baseline Survey - Taita Taveta County*.

Kotey, E. N. (2014). *A survey on methods used in the storage of some varieties of cowpea (Vigna unguiculata L .) and their effect on quality (A case study in Ejura- Sekyedumase District) Department of Horticulture , Kwame Nkrumah University of Science and Technology Kumasi*. (January 2014), 40–50. https://doi.org/10.5251/abjna.2014.5.2.40.50

Kulwa, K. B. M., Mamiro, P. S., Kimanya, M. E., Mziray, R., & Kolsteren, P. W. (2015). Feeding practices and nutrient content of complementary meals in rural central Tanzania: Implications for dietary adequacy and nutritional status. *BMC Pediatrics*, *15*(1), 1–11. https://doi.org/10.1186/s12887-015-0489-2

Kumar, A., Metwal, M., Kaur, S., Gupta, A. K., Puranik, S., Singh, S., … Yadav, R. (2016). Nutraceutical Value of Finger Millet [Eleusine coracana (L.) Gaertn.], and Their Improvement Using Omics Approaches. *Frontiers in Plant Science, 7*(June), 1–14. https://doi.org/10.3389/fpls.2016.00934

Lamboll, R., Martin, A., Sanni, L., Adebayo, K., Graffham, A., Kleih, U., … Westby, A. (2018). Shaping, adapting and reserving the right to play: Responding to uncertainty in high quality cassava flour value chains in Nigeria. *Journal of Agribusiness in Developing and Emerging Economies*, *8*(1), 54–76. https://doi.org/10.1108/JADEE-03-2017-0036

Lansakara, L. H. M. P. R., Liyanage, R., Perera, K. A., Wijewardana, I., Jayawardena, B. C., & Vidanarachchi, J. K. (2016). Nutritional Composition and Health Related Functional Properties of Eleusine coracana (Finger Millet). *Procedia Food Science*, *6*(Icsusl 2015), 344–347. https://doi.org/10.1016/j.profoo.2016.02.069

Mugalavai, V. K., Kinyua, M. G., & Yabann, E. (2018). Quality Characteristics and Nutritional Value of Improved Cassava (Manihot Esculenta) Varieties in Marigat, Baringo County, Kenya. *International Journal of Scientific and Research Publications (IJSRP)*, *8*(11), 828–835. https://doi.org/10.29322/ijsrp.8.11.2018.p8389

Mugwe, J., Immaculate, M., Mucheru-muna, M., & Mugendi, D. (2015). *Adapting African Agriculture to Climate Change*. https://doi.org/10.1007/978-3-319-13000-2

Muoki, P. N., Kinnear, M., Emmambux, M. N., & de Kock, H. L. (2015). Effect of the addition of soy flour on sensory quality of extrusion and conventionally cooked cassava complementary porridges. *Journal of the Science of Food and Agriculture*, *95*(4), 730–738. https://doi.org/10.1002/jsfa.6820

Mwizerwa, H., Ooko Abong, G., Okoth, M., Ongol, M., Onyango, C., & Thavarajah, P. (2017). Effect of Resistant Cassava Starch on Quality Parameters and Sensory Attributes of Yoghurt. *Current Research in Nutrition and Food Science Journal*, *5*(3), 353–367. https://doi.org/10.12944/crnfsj.5.3.21

Ngo, C. (2013). *Re-introduction and Commercialization of Cassava for Improved Livelihoods through Whole Value Chain Model Project Funded by ;*

Nhassico, D., Bradbury, J. H., Cliff, J., Majonda, R., Cuambe, C., Denton, I. C., … Muquingue, H. (2016). Use of the wetting method on cassava flour in three konzo villages in Mozambique reduces cyanide intake and may prevent konzo in future droughts. *Food Science and*

Nutrition, *4*(4), 555–561. https://doi.org/10.1002/fsn3.317

Odhiambo, Paul, Gachanja, J., Gitonga-Karuoro, A., Nyangena, J., Munga, B., Kiriga, B., … Wathuge, N. (2018). *Contributors: Layout*. (9). Retrieved from www.kippra.org

Odhiambo, Phoebe;, Rosemary, M., Mikael, S., Peter, S., & Chris, A.-O. (2014). *Household Baseline Survey Report: Kakamega County*. *1*.

Ohimain, E. I. (2014). The Prospects and Challenges of Cassava Inclusion in Wheat Bread Policy in Nigeria. *International Journal of Science, Technology and Society*, *2*(1), 6. https://doi.org/10.11648/j.ijsts.20140201.12

Okonya, J. S., & Maass, B. L. (2014a). Protein and Iron Composition of Cowpea Leaves: an Evaluation of Six Cowpea Varieties Grown in Eastern Africa. *African Journal of Food, Agriculture, Nutrition and Development (AJFAND)* , *14*(5), 2129–2140.

Okonya, J. S., & Maass, B. L. (2014b). Protein and Iron Composition of Cowpea Leaves: an Evaluation of Six Cowpea Varieties Grown in Eastern Africa. *African Journal of Food, Agriculture, Nutrition and Development (AJFAND)* , *14*(5), 2129–2140.

Olapade, A. A., Babalola, Y. O., & Aworh, O. C. (2014). Quality attributes of fufu (fermented cassava) flour supplemented with bambara flour. *International Food Research Journal*, *21*(5), 2025–2032.

Oloruntola, O. D., Agbede, J. O., Onibi, G. E., & Igbasan, F. A. (2015). *COMPOSITION OF CASSAVA (Manihot spp .) PEELS FERMENTED WITH BOVINE RUMEN LIQUOR AND DIFFERENT NITROGEN SOURCES*. *2*(1), 26–35.

Oresegun, A., Fagbenro, O. A., Ilona, P., & Bernard, E. (2016). Nutritional and anti-nutritional composition of cassava leaf protein concentrate from six cassava varieties for use in aqua feed. *Cogent Food & Agriculture*, *2*(1), 1–6.

https://doi.org/10.1080/23311932.2016.1147323

Pimenta Barros, Z. M., Salgado, J. M., Melo, P. S., & Biazotto, F. de O. (2014). Enrichment of Commercially-Prepared Juice With Pomegranate (Punica granatum L.) Peel Extract as a Source of Antioxidants. *Journal of Food Research*, *3*(6), 179. https://doi.org/10.5539/jfr.v3n6p179

Salvador, E. M., Steenkamp, V., & McCrindle, C. M. E. (2014). Production, consumption and nutritional value of cassava (Manihot esculenta, Crantz) in Mozambique: An overview. *Journal of Agricultural Biotechnology and Sustainable Development*, *6*(3), 29–38. https://doi.org/10.5897/jabsd2014.0224

Senevirathne, H. M., Rajasinghe, N. A., & Perera, D. A. M. (2016). Conspicuous Consumption and Rural Poverty in Farming Community: An Empirical Investigation based on Two DS Divisions in Kurunegala District in Sri Lanka. *Procedia Food Science*, *6*(Icsusl 2015), 73–77. https://doi.org/10.1016/j.profoo.2016.02.015

Sharma, S., Saxena, D. C., & Riar, C. S. (2016). Nutritional, sensory and in-vitro antioxidant characteristics of gluten free cookies prepared from flour blends of minor millets. *Journal of Cereal Science*, *72*, 153–161. https://doi.org/10.1016/j.jcs.2016.10.012

Singh, E. S. (2016). Potential of Millets: Nutrients Composition and Health Benefits. *Journal of Scientific and Innovative Research*, *5*(2), 46–50. Retrieved from www.jsirjournal.com

Streck, N. A., Pinheiro, D. G., Zanon, A. J., Gabriel, L. F., Rocha, T. S. M., De Souza, A. T., & Da Silva, M. R. (2014). Effect of plant spacing on growth, development and yield of cassava in a subtropical environment. *Bragantia*, *73*(4), 407–415. https://doi.org/10.1590/1678-4499.0159

Suryaningrat, I. B., Amilia, W., & Choiron, M. (2015). Current Condition of Agroindustrial Supply

Chain of Cassava Products: A Case Survey of East Java, Indonesia. *Agriculture and Agricultural Science Procedia*, *3*, 137–142. https://doi.org/10.1016/j.aaspro.2015.01.027

Tharise, N., Julianti, E., & Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. *International Food Research Journal*, *21*(4), 1641–1649.

Uchechukwu-Agua, A. D., Caleb, O. J., & Opara, U. L. (2015). Postharvest Handling and Storage of Fresh Cassava Root and Products: a Review. *Food and Bioprocess Technology*, *8*(4), 729–748. https://doi.org/10.1007/s11947-015-1478-z

Vanhanen, L. P., & Savage, G. P. (2006). The use of peroxide value as a measure of quality for walnut flour stored at five different temperatures using three different types of packaging. *Food Chemistry*, *99*(1), 64–69. https://doi.org/10.1016/j.foodchem.2005.07.020

Wanapat, M., & Kang, S. (2015). Cassava chip (Manihot esculenta Crantz) as an energy source for ruminant feeding. *Animal Nutrition*, *1*(4), 266–270. https://doi.org/10.1016/j.aninu.2015.12.001

Zainuddin, I. M., Fathoni, A., Sudarmonowati, E., Beeching, J. R., Gruissem, W., & Vanderschuren, H. (2018). Cassava post-harvest physiological deterioration: From triggers to symptoms. *Postharvest Biology and Technology*, *142*(September 2017), 115–123. https://doi.org/10.1016/j.postharvbio.2017.09.004

APPENDIX

Appendix 1: Survey Questionnaire

Department of Food Science, Nutrition and Technology

SEMIs-Cassava project

Project Title: RU/2018/CARP+/04:

Capacity building for micro propagation and certification of cassava planting materials to enhance productivity, incomes and food and nutrition security for small holder farmers in Coastal Kenya

Introduction:

The goal of the project is to increase cassava productivity and reduce the effect of major cassava diseases caused by viruses and bacteria. The current practice is that farmers acquire planting materials from each other or KALRO centers and in the process this has been a very effective method of distributing infected or diseased planting materials. In addition, many cassava producing countries in Africa including Kenya have no protocol to produce and certify healthy cassava planting materials. Thus, the integration of greenhouse technology as a protected environment will allow KEPHIS to certify cassava planting materials emanating from these greenhouses to ensure that the multiplication and distribution of these materials are disease

CASSAVA BASELINE SURVEY QUESTIONNAIRES

KILIFI AND TAITA TAVETA COUNTY.

Introduction and verbal consent taking

My name is ……………………………………………..undertaking this research on behalf of the University of Nairobi and RUFORUM on Capacity building for micro propagation and certification of cassava planting materials to enhance productivity, incomes and food and nutrition security for small holder farmers in Coastal Kenya. I would like to invite you on behalf of the University of Nairobi to take part in the study that is aimed at increasing productivity of cassava in this region. I am requesting you to help us learn more about cassava production, marketing and utilization. All that you will say will be confidential for purposes of this study and participation is voluntary. I f you agree, I will ask you some questions.

Yes ( )

No ( )

SECTION 1

Data Collection Guidelines

Sampling Date: ………………… Serial Number……………………..

	County………………………. **Sub-county……………………………..…** **Location ……………………………….** **Village …………………………………..**	**Ward…………………………………………….** **…** **GPS coordinates………………………………..** **Longitude ________________________** **Latitude__________________________** **Altitude__________________________**
	Name of Farmer **………………………………………………………………….**	**Sex: A)**Male( ) **B)**Female ( ) **Age:** 1) <35 (youth) 2) Middle age 36-51 3) >51-60 upper middle age 4) >60 retirees
	Head of household **...**	**Farm size in acres** 1) < 2 ( ) 2) 2-5 ( ) 3) 5- 15 ( ) 4) 4)15-50 ( ) 5) 50 + ( )
	Occupation	1) Formal Employment [ ] 2)Casual Employment Time [ ] 3)Business Man [ ] 4) Full Farmer [ ] 5)Other (Specify)
	Academic Qualification	**1) None ( )** **2) Primary ( )** **3) Secondary( )** **4) Tertiary ( )**
	Annual rainfall (mm) **Long rains.................. Short Rains..........................**	**Temperatures (^{0}c)** **Long season ....** **Short season................**

SECTION 2

Land preparation

1. When do you expect your rain and when do they end?

   Short rains …………….
   Long rains ……………….
2. a) Have you ever experienced non formal agricultural training?

   1. yes ( )
   2. No ( )

   b) If yes, who did the training?
   1. Government ( )
   2. Non-Government ( )

3. When do you do your land preparation
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………….
4. How do you prepare your land for cassava production?
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………….
5. Do you practice any soil conservation management?

1) Yes
2) No

5b) if yes, which soil conservation measures?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………

6. What is the total current area under crops? (categorize based on top categories

   ………………………………………………………………………………..

7. a)What is the total current area under cassava? categorize as above

   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………

……
………………………………………………………………………

7. b) On the farm where you have cassava, which was the previous crops ?

……
……
……
………………………………………………………………………

8. Why do you grow cassava?

……
……
……
……
……
……
………………………………………………

8b) Which varieties do you prefer

Variety	priority
…......................................	....
....	....
....	....
....	....
....	....
....	....

8c) Why prefer that variety (list)

1……………………………………………………………………………..
2……………………………………………………………………………..
3……………………………………………………………………………..

9. a)When did you start growing the improved cassava variety? (code in terms of years) recall of 10 years

Variety	Year
………………………… …	………………
…………………………….	………………
…………………………….	………………
…………………………….	………………
…………………………….	………………

……………………………...   ………………

9.b) When did you start growing e.g shibe

……………………………………………………………

10. What is the spacing for your cassava crop?

…………………………………………………………..

11. a)Do you intercrop or plant cassava alone?

1. Yes ( )   2. No ( )

11. b)If Intercrop, which crops do you usually plant between cassava? (list)

Crops intercropped	order of priority
....	....
....	....
....	....
....	....
....	....

11c) Why you do intercrop? (list reasons)

1…………………………………………………………………..
2…………………………………………………………………..
3…………………………………………………………………..
4…………………………………………………………………..

12.a)Where did you source your planting material? (tick appropriately)

1)Local market ( )
2) Own seed ( )
3) Neighbors ( )
4) KALRO ( )
5) Other, specify ………………………………………………………………

12b) What is the reliability of the source of the planting materials?

1) Extremely reliable( )
2) Moderately reliable ( )
3) Low ( )

12c) How frequently do you source your planting materials?

……………………………………………………………………………………..

13.a) Do you use farm inputs?

1. Yes ( )   2. No ( )

13b) If yes which one? (list) Fertilizer/manure?

…………………………………………………………………………………………………..……
………………………………………………………………………………………

13.c)When do you apply the input?(fertilizer/manure)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

14.a)When do you plant?

1) Long rains ( ) 2) Short rains ( ) 3). Both ( )

14. b) Specify the month

……………………………………………………………………………………………

15. Do you experience pest and disease infestations?

1) Yes ( ) 2) No ( )

15.b) If yes, name the common pests and diseases

Pests	Diseases
....	....
....	....
....	....
....	....
....	....
....	....

15.c) How do you identify different pests and diseases?

Signs

………………………………………………………………………………………………………
………………………………………………………………………………

Symptoms

………………………………………………………………………………………………………
………………………………………………………………………………

15.d)Do you practice scouting for pests and diseases?

1. Yes ( ) 2. No ( )

15.e)If yes, how often do you scout?

A) regularly ( )B) Rarely ( )C)Never ( )

15.f)When are the stated pests and diseases most prevalent?

Pests	when
____________________	________________________
____________________	________________________
____________________	________________________
____________________	________________________

Diseases	When
____________________	________________________
____________________	________________________
____________________	________________________

15.g) Which management practices do you use? on pests and diseases. (list)

1………………………………………………………………………………

2………………………………………………………………………………

3……………………………………………………………………………..

4……………………………………………………………………………..

5……………………………………………………………………………..

6……………………………………………………………………………..

15.h)If chemicals, which type of chemicals do you use?

……………………………………………………………………………………………

……………………………………………………………………………………………

16.a) Do you own a sprayer?

1) Yes ( ) 2 NO ( )

16. b)If no, Where do you borrow the sprayer from?

……………………………………………………………………………………………

……………………………………………………………………………………………

16.c)How often do you spray

……………………………………………………………………………………………

17.a). Have you ever received any information on cassava production?

1) Yes ( ) 2) No ( )

17.b))If yes, what is/are the source of the information

1) Extension staff ( )
2) Media -Radio/T. V/Newspaper ( )
3) Agro input dealer ( )
4) From other farmers ( )
5) Research ( )

17.c)What kind of technical information do you receive ?

1)Extension staff

……………………………………………………………………………………

…………………………………………………………………………………..

2) Media **-**Radio/T. V/Newspaper

……………………………………………………………………………………

…………………………………………………………………………………..

3) Agro input dealer

……………………………………………………………………………………

…………………………………………………………………………………..

4) from other farmers

……………………………………………………………………………………

…………………………………………………………………………………..

5) Research
…………………………………………………………………………………………
……………………………………………………………………………………..

17.d) How often do you receive the information on cassava
1. Weekly ( ) 2. monthly ( ) 3.quarterly ( )
4. Semiannually ( ) 5. annually ( )

18. Where do you get information for new variety?
…………………………………………………………………………………………
……………………………………………………………………………………..

20. What challenges do you face in cassava production?
…………………………………………………………………………………………
……………………………………………………………………………………..
…………………………………………………………………………………………
……………………………………………………………………………………..
…………………………………………………………………………………………
……………………………………………………………………………………..

SECTION 7 (SAMWEL)

PART A: LIFESTYLE

1. a)Did you consume any cassava/cassava based products in your household in the past one year?
   A) Yes, B) NO

1.b)If yes, which ones?
………
………
………
……………………………………………………………………………

2. a)Where did you source the cassava or cassava based product from?

   1-Farm [ ] 2-Market [ ] 3- Vendors [ ]
   4-Any other [ ] **specify……………………………………………………………………….**

2.b)Why do you prefer the above named source?
………
………
………
……………………………………………………………………………

2.c)How frequently do you buy and/or consume these cassava roots (from the above)?
1-Everytime [ ] 2-Just at times [ ] 3-Rarely [ ]

2.d)Is there any other place you get your cassava roots for household consumption apart from the above place?

1-YES [ ]   2-NO [ ]

2.e)If yes, please specify……………………………………………………………………….

3. Are the varieties you frequently consume bitter or sweet?

1-Sweet [ ]   2-Bitter [ ]

4.When does your household consume cassava based products most? Specify.

…………………………………………………………………………………………………

5.Are there any benefits you derive from consuming cassava roots from this preferred source? Kindly state a few

……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………

6.a)Do you think these cassava roots are safe for your consumption?

1-Yes   2-NO

6.b)If yes,Kindly list some things that inform your opinion about the safety of these cassava variety (s).

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………

7.a)In your households are there family members exempted from cassava based meals and products?

1-Yes [ ]   2-No [ ]

7.b)If yes,kindly list them

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
…………………………………………………………………………

8.a)In your household, who consumes cassava based products and roots most?

1-Women [ ]   2-Men [ ]   3-Children [ ]   4-All [ ]

8.b)Does any of the family members exhibit any form of reactions after taking these cassava roots/products?

1-Yes [ ]   2-NO [ ]

8.c)If YES, kindly list any of these frequent reactions exhibited by these members.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………

8.d)How do you manage the above listed reactions?

1-Sought medical attention [ ] 2- The symptoms dissipated [ ]

3-Resulted to death [ ]

PART B: CONSUMPTION PATTERNS

1.In what form do you consume the cassava roots?

1- Raw   2- cooked   3- flour   4- any other

2.a)List the cassava based and processed products that you frequently consume.

……
……
……
……
……
………………………………………………………………

2.b)From where do you get these processed cassava products?

1-Individual [ ] 2- Wholesale stores [ ]

3-Supermarket and other Retail stores [ ]

4-Cooperative [ ]

5-Any other, please specify……………………

2.c)If flour, briefly give a description how the above is prepared?

……
……
……
……
……
………………

3.Kindly quantify the cassava roots and flour you alone consume per day?

……………………………………………………………………………………………………

4.What other uses do you have for cassava roots? Tick the correct options while ranking them from5-most important to 1-least important.

	Rank
Processing for subsistence [ ]	…………………………
Resale [ ]	…………………………
Processing for sale []	…………………………..
Livestock feed [ ]	…………………………..
Non-food or feed uses [ ]	……………………………

5.a)Do you also consume cassava leaves as vegetables?

1-Yes [ ] 2- No [ ]

5.b)If Yes, how are they prepared?

……
……
……
…………………………………………………………………………………

6.Do you consume cassava flour in your household? Please list the key uses if any in your household.

……
……
……
…………………………………………………………………………………

7.Are there any other food products that you consume in which cassava has been incorporated? Please explain their preparation.

……
……
……
……………………………………………………………………………

PART C: TREATMENT, HARVESTING, STORAGE AND HANDLING

1.a)What time of the day do you normally harvest cassava roots/leaves or stems?

1) Early morning [ ] 2) Late morning [ ] 3) afternoon [ ]

4) Evening [ ] 5) other (specify

A)leaves ………

B) roots ………….

C) stems …………….

1.b)What are some of the reasons for harvesting at this time?

1= market requirements [ ] 2= labor availability [ ] 3= temperatures [ ] 4= other(specify……………………………….

A) leaves ………………

B) stems………………

C) roots……………………….

1.c) what method of harvesting do you use

1) piecemeal [ ] 2) whole [ ]

A) roots ………………..

B) leaves ………………

C stems ……………….

2.At what age do you normally harvest cassava roots/leaves/ stems?

A) roots ………………………………………………………………..

B) leaves ………………………………………………………………

C stems ………………………………………………………………..

3.If roots are damaged at the time of harvest , what do you do with them ?

Mechanical damage

……
……
……
……………………………………………………………………………

Pest damage

……
……
……
……………………………………………………………………………

Rot
……
……
……
………………………………………………………………………………

4.At the farm level, what containers are used during handling and transportation from farm

1) Baskets [ ] 2) buckets [ ] 3) gunny bags [ ] 4) plastic bags [ ]

5) others (specify)……………………………………………………………………

5.What is the destination of cassava after harvesting?

1) Homestead [ ] 2) local open market [ ] 3) bulking /processing [ ]

6.What is the transportation means from the farm?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

7.a)Do you preserve cassava roots/ leaves /stems?

1) Yes 2) No

7.b)If yes, how do you preserve the cassava leaves/roots / stems?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………

7.c)Where did you learn about the preservation?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………………………………………

7.d)What is the length of the preservation time ?

……………………………………………………………………………………………..

1. Do you process cassava?

1) Yes 2) No

B) List some of the cassava varieties and the respective product you make from them

Variety product

I. ……………
II. …………………
III. ………………..

IV. …………………..
V. ……………………….

C) What are the reasons for using the above varieties to produce the product?

……
……
……
……………………………………………………………………………………

D) How long after harvesting the roots do you process?

2. Do you store cassava products?

1) Yes 2) NO

b) if yes, which cassava products do you store?

I. …………….
II. ……………….
III. ………………….
IV. …………………….
V. …………………………

3. Do you store cassava in the same store with other products

1) Yes 2) No

B) if yes, name some of the crops cassava is stored with

I. ………………..
II. ………………..
III. …………………
IV. ……………………..
V. ………………………..

4. How do you package your products for storage?

……
……
…………………………………………………………………………………………

B) where do you store your cassava products

1) on floor in the house 2) on raised platform in the house 3) in granary 4) other (specify)

C) how long do you normally store each of the products before utilization or sale

Product length of storage main cause of loss

I. …………………..
II. …………………….
III. ……………………….
IV. ……………………….
V. …………………….

D) what do you do with the damaged/ spoilt Cassava

Product	damaged/ broken	spoilt/molded/caked

1) ………………………………………………………………………………..
2) …………………………………………………………………………………..
3) …………………………………………………………………………………..
4) ………………………………………………………………………………….
5) …………………………………………………………………………………

5. Do you need feed your livestock on cassava products /by products?

1) Yes 2) No

B) If yes which products or by products do you feed your livestock

Cassava product	livestock type

a If no , why?

C) What are the possible signs of contamination that you know can render cassava roots or products unwholesome?

………
………
………………………………………………………………………………………………

D) Can you tell if your cassava is unfit for consumption?

1-Yes 2-NO

E) If YES, how do you know it's not fit?

Please list some examples
………
………
………
………
………
……………………………………………………………………

F) How do you ensure the cassava are safe for consumption in case any contaminants are found in them?

………
………
………………………………………………………………………………………………

Marketing of cassava and cassava products

6. What cassava products do you sell?

1) Leaves 2) stem 3) fresh roots 4 dry chips 5)flour 6)animal feeds 7) other processed products

2) What type of packaging do you use for your products for sale?

3) Product packaging / material Quantity in container value of product in package

I. ……………………………………………………………………………………..
II. ……………………………………………………………………………………………….
III. …………………………………………………………………………………………….

7. Where do you sell your product?

WASTE MANAGEMENT

8. How do you manage waste from cassava production

Peling

……
……………………………………………………………………………………..

Washing

……
……………………………………………………………………………………………..

Pressing

……
………………………………………………………………………………………………..

Milling

……
……

What problems do you face during production processing and marketing of cassava products?

9. Any comments on cassava you would wish to share

……
……
……………………………………………………………………………………..

THANK YOU
FOR PARTICIPATING

Appendix 2: Originality Report

Source of variation	**Ash**	**Carbohydrates**	**Fat**	**Fibre**	**Moisture**	**Protein**	**Energy (Kcal)**	**Iron**	**Zinc**	**Vitamin A**	**Vitamin C**
Sample	50.2*	0.002*	37.1*	89.8*	656.4*	660.7*	1064.9*	0.002*	2.6*	3.6*	398.0*
Treatment	18.3*	0.004*	19.0*	18.8*	15125.2*	117.6*	1256.7*	0.001*	116183.1*	299.9*	110.4*
Sample x Treatment	22.7*	0.001*	32.8*	47.7*	765.4*	301.4*	501.9*	0.004*	167.1*	14.8*	102.6*

Appendix 3: Nutrisurvey output for flour formulations

5.4.1 Nutrient content of the flour blends

5.4.1.1 Nutrisurvey output for Total analysis of GPF2 (20% cowpea leaves, 50% Dried cassava leaves and 30% millet.)

Table 5.2 represents the nutrisurvey output for GPF2. The output generated highlights the nutritional composition of the composite flour, with energy yield of 316kcal, protein 7.3g and carbohydrates 72.1g (88%)

Table 5. 7 Nutrisurvey output for Total analysis of GPF2 (20% cowpea leaves, 50% Dried cassava leaves and 30% millet) take this to methods and have proper table or delete

Nutrient	nutritional composition in 100g	nutrients	nutritional composition in 100g
Energy	316.7 kcal	Iron absorb.	0.2 mg
Protein (9%)	7.3 g	Vit. B1	0.3 mg
Fat (3%)	1.0 g	Vit. B2	0.1 mg
Carbohydrates. (88%)	72.1 g	Niacin equiv.	2.8 mg
Dietary fiber	9.3 g	Vit. B6	0.5 mg
Phytic acid	410.0 mg	Pantoth. Acid	0.7 mg
Calcium	118.1 mg	Folic acid eq.	130.8 µg
Ca absorb.	29.9 mg	Vit. B12	0.0 µg
Magnesium	48.1 mg	Vit. C	36.0 mg
Zinc	1.4 mg	Ret. equiv.	5.0 ug
Zn absorbed	0.2 mg	Grains roots	80.0 g
Iron	3.1 mg	Legumes_nuts	20.0 g

Figure 5.1 indicates the percentage fulfillment of the recommended daily nutrient intake for GPF2. The formulation gives 100% energy required, 76% protein, 30% calcium, 89% magnesium for who? Why calcium and magnesium now?

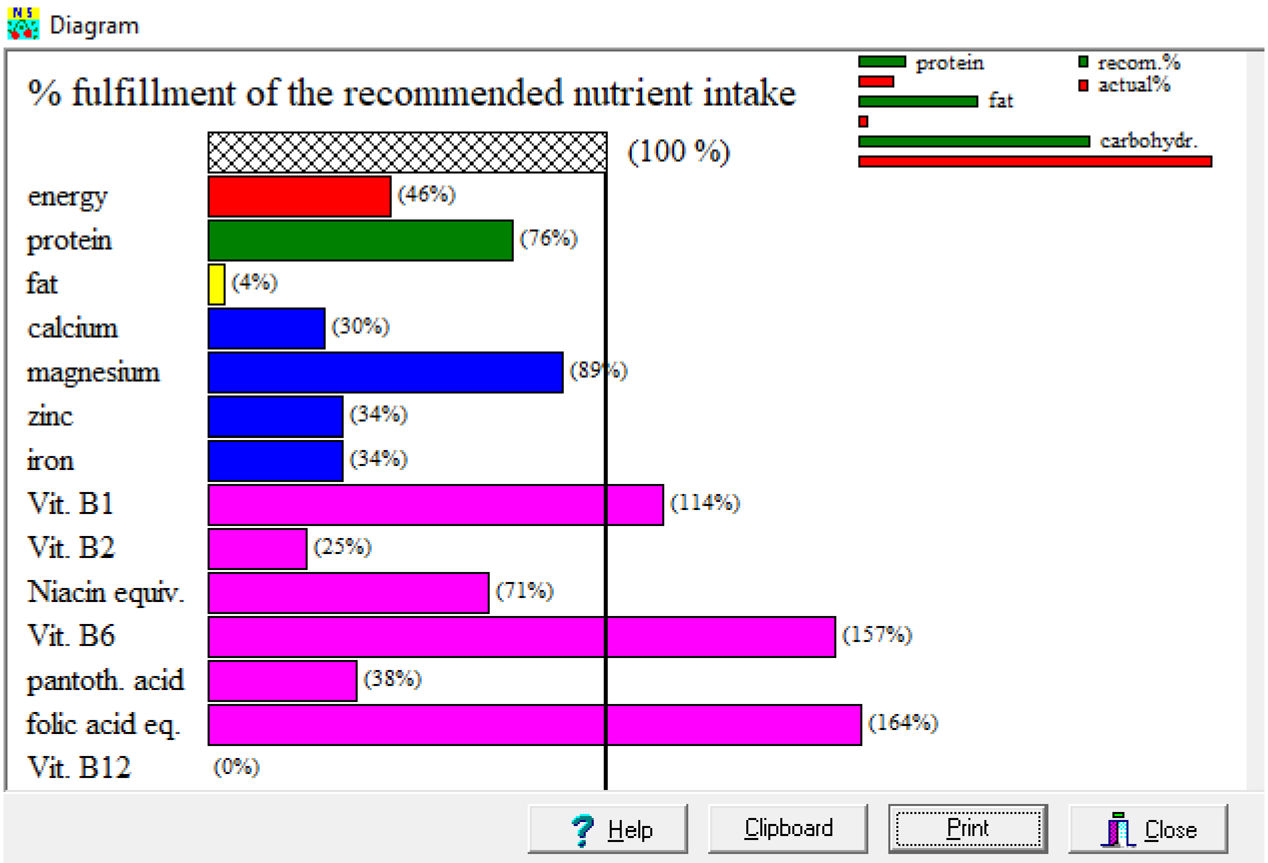

Figure 5. 1 fulfillment of recommended intake

Figure 5. 3 percentage nutrient fulfilment from composite flour 1 (20% cowpea leaves, 50% Dried cassava leaves and 30% millet

5.4.1.2 Nutrisurvey output for Total analysis of GPF3: (10% cowpea leaves, 50% cassava roots and 40% millet)

Table 5.3 highlights the nutrisurvey output for composite flour GPF3. The energy of the flour is 318kcal, protein of 6.0g and carbohydrates 74.3g and dietary fiber of 8.9g

Table 5. 8 Nutrisurvey output for Total analysis of GPF3: (10% cowpea leaves, 50% cassava roots and 40% millet)

nutrient	nutritional composition in 100g	nutrient	nutritional composition in 100g
Energy	318.9 kcal	Iron absorb.	0.2 mg
Protein (9%)	6.0 g	Vit. B1	0.3 mg
Fat (3%)	1.0 g	Vit. B2	0.1 mg
Carbohydrates. (88%)	74.3 g	Niacin equiv.	2.5 mg
Dietary fiber	8.9 g	Vit. B6	0.5 mg
Phytic acid	367.5 mg	Pantoth. Acid	0.6 mg
Calcium	139.3 mg	Folic acid eq.	76.9 µg
Ca absorb.	35.2 mg	Vit. B12	0.0 µg
Magnesium	36.8 mg	Vit. C	36.0 mg
Zinc	1.2 mg	Ret. equiv.	5.0 ug
Zn absorbed	0.2 mg	Grains roots	90.0 g
Iron	2.7 mg	Legumes_nuts	10.0 g

Figure 5.2 indicates the percentage nutrient fulfilment GPF3composite flour 1 (10% cowpea leaves, 50% Dried cassava leaves and 40% millet). The formulation achieves 55% of daily required protein, 35% Calcium, 61% magnesium and 45% Iron.

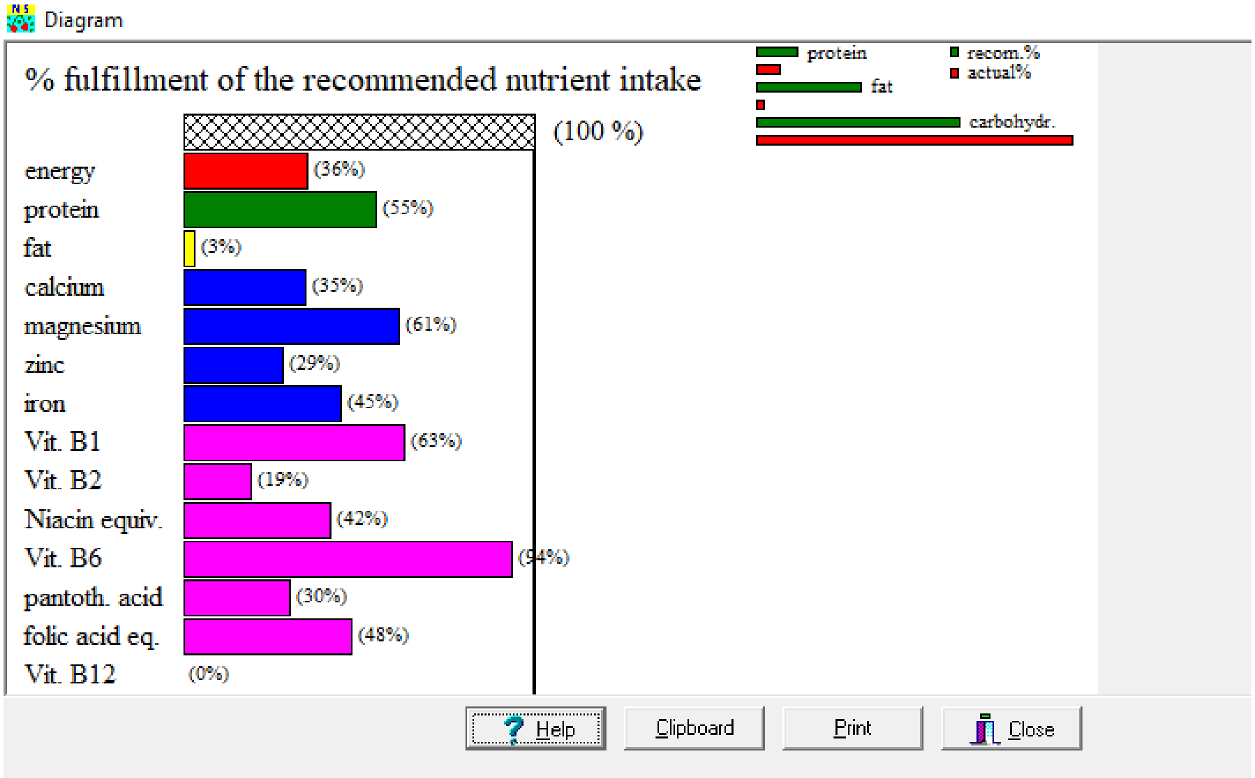

Figure 5. 2 Fulfillment of recommended intake

5.3.4.3 Nutrisurvey output for Total analysis of GPF4: (15% cowpea leaves, 60% cassava roots, 25% millet)

Table 5.4 indicates the nutritional composition of GPF4 composite flour. The composite flour has energy of 316kcal, protein of 6.3g, carbohydrates 73.2g and dietary fiber of 8.1g

Table 5. 9 Nutrisurvey output for Total analysis of GPF4: (15% cowpea leaves, 60% cassava roots, 25% millet)

nutrient	nutritional composition in 100g	nutrient	nutritional composition in 100g
Energy	316.4 kcal	Iron absorb.	0.2 mg
Protein (9%)	6.3 g	Vit. B1	0.3 mg
Fat (3%)	0.9 g	Vit. B2	0.1 mg
Carbohydrates. (88%)	73.2 g	Niacin equiv.	2.6 mg
Dietary fiber	8.1 g	Vit. B6	0.5 mg
Phytic acid	349.8 mg	Pantoth. Acid	0.7 mg
Calcium	105.8 mg	Folic acid eq.	106.4 µg
Ca absorb.	26.9 mg	Vit. B12	0.0 µg
Magnesium	42.2 mg	Vit. C	43.2 mg
Zinc	1.2 mg	Ret. equiv.	5.4 ug
Zn absorbed	0.2 mg	Grains roots	85.0 g
Iron	2.8 mg	Legumes_nuts	15.0 g

. Figure 5.3 indicates percentage nutrient fulfilment for composite flour GPF4 (15% cowpea leaves, 60% Dried cassava leaves and 25% millet) giving 35% daily energy requirement, 57% protein and magnesium 70% and 30% zinc.

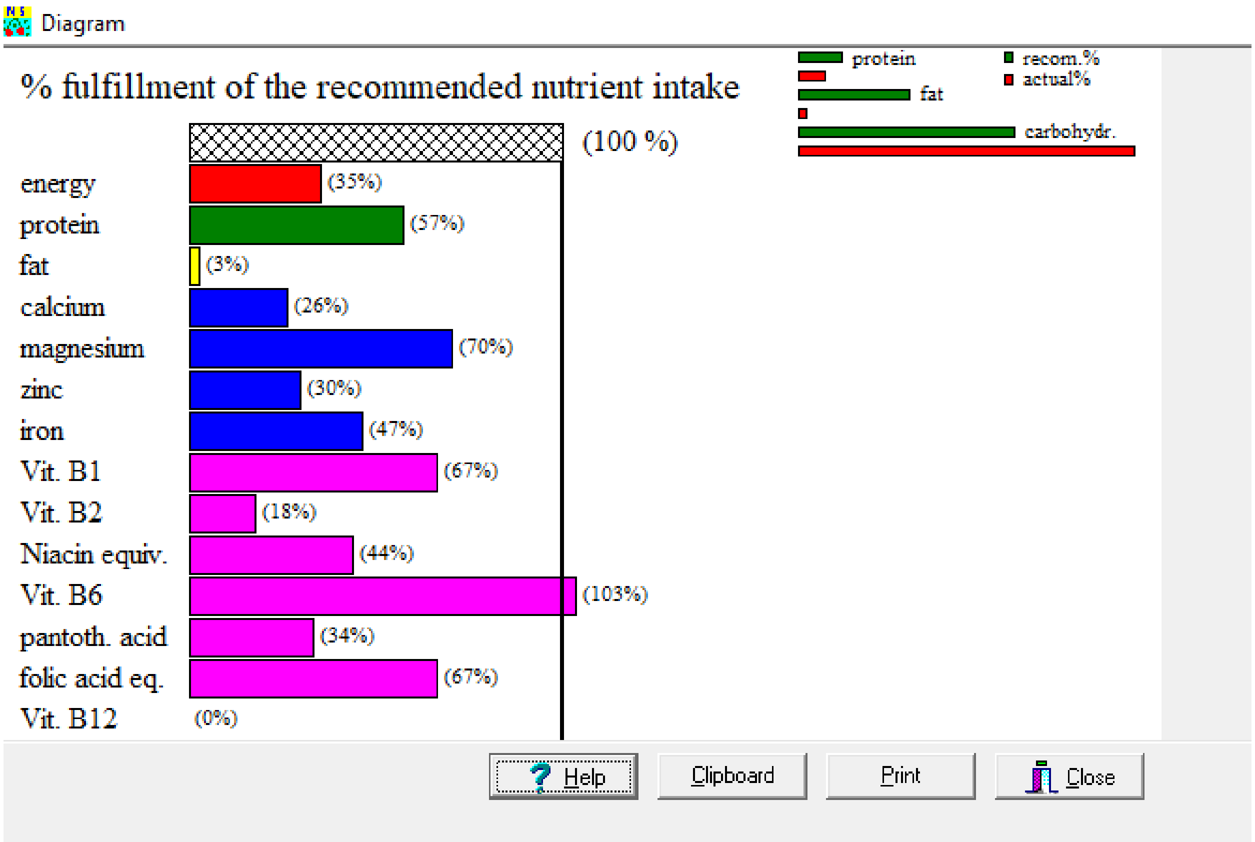

Figure 5. 3 fulfillment of recommended intake

Figure 5.3 percentage nutrient fulfilment for GPF4 (15% cowpea leaves, 60% Dried cassava leaves and 25% millet all these nutrisurvey need to go to appendix.