STUDY OF SUITABILITY OF CASSAVA AND COWPEA FLOURS FOR MAKING BREAD

BY

SERAFINA LÍDIA VILANCULOS

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ABSTRACT

This study was done in Tanzania and Mozambique to assess the effect of cassava and cowpea flours singly and in combination in bread making and the degree of acceptability of the bread. Five to 20% cassava and 5 to 30% cowpea were used as wheat flour diluents. As the amount of diluents increased, the loaf volume decreased. The bread size ranged from 560 ml for 30% cowpea bread to 890 ml for 100% wheat bread and from 420 to 620 ml for the pan bread, the highest value being for whole wheat bread and the lowest for 30% cowpea composite bread. The bread weight increased for cowpea composite bread and the combination cassava-cowpea composite breads, ranging from 214 to 250 g for wheat bread and from 260 to 290g for pan bread, the highest values being for 30% cowpea bread and the lowest for 5% cassava composite bread. The specific loaf volumes were 2.39 to 4.07 ml/g for wheat breads and 1.45 to 2.31 ml/g for the pan type breads. Baking losses decreased as the amount of cowpea increased. However, cassava inclusion showed no decrease in baking losses. Cassava composite breads decreased protein content but increased mineral content. Cowpea bread had increased nutrients. The 30% cowpea bread was least accepted as also reflected in the lowest buying preference. For the pan bread, the lowest value was for the combined 10% cassava-5% cowpea bread and the highest value for 10% cowpea bread. This study concluded that up to 15% substitution, the formulation results were promising. Beyond 15% there were changes in organoleptic attributes and poor gas retention reduced loaf volume. Incorporation of cassava or cowpea flour gave a compact structure at higher substitution levels. Increasing levels of cowpea flour in the blends resulted in increased ash and protein and colour changes. The nutrient gains when cowpea is used in composite flour formulation need exploitation.

DECLARATION

I, SERAFINA LÍDIA VILANCULOS, do hereby declare to the senate of Sokoine University of Agriculture, that the work presented here is my own creation and has not been submitted for a degree award in any other University.

____________________________ _______________________

SERAFINA LÍDIA VILANCULOS Date

(MSc Candidate)

The above declaration is confirmed

____________________________ _______________________

Dr. MPAGALILE, J.J. Date

(1st Supervisor)

____________________________ _______________________

PROF. LASWAI, H.S. Date

(2nd supervisor)

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DEDICATION

To the memory of my late son **Agnaldo Maguino Jofane** who passed away in September 2007. Son, I miss your physical presence, love, peace flouring from you, and sense of humour. May Almighty God rest your soul in eternal peace, Amen.

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LIST OF ABBREVIATIONS AND SYMBOLS

AOAC	Association of Official Analytical Chemists
Accept.	Acceptability
CAMV	Cowpea Aphid Mosaic Virus
Carbohyd.	Carbohydrates
CBSD	Casssava Brown Streak Virus disease
CBSV	Cassava Brown Streak Virus
CDI	Centre for the Development of Industry
C.	Crude
CGMV	Cowpea Golden Mosaic Virus
cm	Centimetre
Comp.	Composition
D.	Dry
FAO	Food and Agriculture Organization of the United Nations
Form.	Formulations
FIIRO	Federal Institute of Industrial Research, Oshodi, Nigeria
g	gramms
km	Kilometre
IIAM	Instituto de Investigação Agrária de Moçambique
ISI	International Starch Institute
Ltd	Limited
LDA	Limited
ml	millilitre
mm	Millimetre
mg	Milligram
nm	Nanometre

Pref.	Preference
ppm	Parts per million
R.	Room
S.	Soaking
SPSS	Statistical Package for the Social Science
w/w	Weight for weight
Wht.cas.cow	Wheat:cassava:cowpea
ºC	Degree Centigrade
Temp.	Temperature
%	Percentage
&	And
±	Plus or minus

CHAPTER ONE

1. 0 INTRODUCTION

1.1 Background information

Cassava and cowpea are important crops in Mozambique like in other parts of Africa. Cassava crop contributes significantly to the diets of over 800 million people, with per capita consumption averaging 102 kg per year (FAO, 2001). Cassava use in Africa is equivalent to 62% of total world production (Westby, 2002) and the total world cassava is expected to increase to 275 million tonnes in 2020 (Scott *et al.*, 2000). Millions of people de on cassava in Africa, Asia and Latin America (FAO, 2004).

In Mozambique, cassava production is estimated to occupy one third of the total production area and in 2004/05 the global production was 6.6 millions tonnes (Ministério da Agricultura, 2006). This crop is vital for both food security and income generation. Nutritionally, cassava is a cheap source of carbohydrates but poor protein source while cowpea is a cheap source of proteins. Therefore cowpea can be used as an improvement of cassava products or diets. In addition, cassava can be improved in nutritive value through fortification with cowpea and other sources of proteins, likewise diversifying products that could be used to solve the problem of malnutrition.

At the same time cassava can be used as a diluent for wheat flour products and other cereals like barley. Also, it can be used as a source of energy if transformed into high quality products by high income people, such products include high quality cassava flour for bread in composite flour bread and even for alcohol generation, thus saving foreign currency. It can as well be used as a sweetener and other important uses. This crop is considered to have high content of dietary fiber, magnesium, sodium, riboflavin, thiamin and nicotinic acid (Bradbury and Holloway, 1988).

In 2004/05 Mozambique produced 201 000 tonnes of beans (Ministerio da Agricultura, 2006), but the exact amount of cowpea is not well understood. It is estimated that annual world cowpea grain production stands at 3 million tonnes (http://www.africancrops. net/rockefeller/crops/cowpea/index). Cowpea is considered to be tolerant to drought and better adapted to sandy soils. All cultivated cowpea varieties are considered warm season and adapted to heat and drought conditions. As in most legumes, the amino acid profile complements cereal grains. As a legume, cowpea fixes its own nitrogen, and does not need nitrogen fertilizer (http;//www.cowpea .org/ node/7).

Wheat is increasingly becoming unstable in price and supplies, is also a poor crop, Oyenuga (1972); Okaka and Isieh (1990). Regulations in many countries require that wheat flour be enriched to replace nutrients lost in the production of refined flour (http://www.en. wikipedia.org/wik i/Flour #Wheat_flour).

1.2 Problem statement and justification

In Mozambique, cassava is the second staple food after maize and is eaten in fresh form and processed into *Rali* and flour to make flour-based products like *Chima* (*ugali* like product). *Rali* is an important product in Gaza and Inhambane provinces and can be eaten with tea at breakfast time, as rice and *ugali*, but is poor in protein because is processed from cassava, which is low in proteins. Although there are some references talking about composite bread using cassava flour, in Mozambique such products are not commonly used. Mozambicans in towns and rural areas consume bread during breakfast time, and it serves as snacks at school.

As an alternative, people in rural areas use fresh cooked cassava for breakfast and for children it is used as snack at school. Also a total reliance on cassava during drought seasons lead to malnutrition due to the fact that cassava is limited in nutrients, particularly protein. Although there has been some research work investigating the use of cassava flour in making composite breads worldwide (FAO, 1987), such products are not commonly used in Mozambique. Furthermore, since the country does not produce wheat, it becomes expensive for people especially in rural areas and for the country to access wheat flour, because foreign currency will be needed to purchase wheat flour from outside the country. Replacing wheat flour with cassava flour decreases protein content in the resulting bread, and this is prompting growing interest in fortifying wheat flour with high lysine material, such as cowpea flour, to improve the essential amino acid profile of baked food products (Hallén, 2004).

1.3. Objectives

1.3.1. Main objective

In this study the main objective was to formulate nutritious and acceptable cassava–wheat–cowpea composite bread as a strategy to diversify and increase cassava and cowpea utilization in Mozambique.

1.3.2 Specific objectives

The specific objectives of this study were**:**

(i) To determine the correct proportions of wheat, cassava and cowpea flour in the formulated flours for use in bread.

(ii) To determine physical and chemical properties of the composite bread and evaluate acceptability by consumers.

(iii) To determine the shelf life of the formulated breads.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Breads are a group of staple food prepared by soaking, steaming or frying dough, consisting of flour and water. Salt is present in most cases, and usually a leavening agent is used. The simplest breads are made from grains such as wheat, oats, barley, rye, millet, and corn mixed with water. Natural white flour has a slightly yellow colour from pigments in wheat that tend to whiten with time. Wheat flour is particularly well suited to bread making because it contains glutelin and gliadin, two proteins that combine with water to form a substance called gluten. Other flour grains and seeds are often combined with wheat flour to make breads with different colours, textures, and flavours (Hoseney, 1994). According to the available literature it is recommended that for bread making, wheat flour with protein content of 10.5% or above is needed (Hoseney, 1994).

Due to the high price of wheat flour several countries are trying to mix wheat flour with flour made from other cereals, roots, seeds and fruits like plantain, soybean (Olaoye *et al.*, 2006). Use of such composite flour encourages the agricultural sector, reduces wheat imports in many developing countries and diversifies products. Many dilutions have been done to produce products like cassava bread, composite bread using pumpkin seed flour as diluent (Giami *et al*., 2004). Dilution flours are used sometimes for improving nutritional quality, because no legume or cereal singly can provide all the amount of nutrients. Mixing legumes with cereals in the diet improves overall nutrition (http://www.cowpea.org/node/7). Products made from composite flours have been well accepted in Colombia, Kenya, Brasil, Nigeria, Senegal, Sri Lanka and the Sudan (Dendy, 1992). In Mozambique, the bread type used is the pan bread or French bread. Pan is cooked directly on clay tiles, requiring 300ºC as compared to ‘loaf ‘type breads that require only 180ºC to 240ºC. It is cooked in pans and use any kind of oven (http://www. Repp.org//resources/stoves/ Scott/ Mozambique / Portuguese). French bread is lean as it contains no fat, lasting about a day at most. This is why people buy it daily in Mozambique and other countries. French bread is eaten at all meals, and forms the most important part of breakfast and is typically made with flour, water and yeast (http://www. Repp. org//resources /stoves /Scott / Mozambique/Portugese). There are two ways to make authentic French bread, one from a straight yeast method and the other from a starter.

2.2 The history of bread

Bread is one of the oldest prepared foods, dating back to the Neolithic era (Samuel, 2000). The first breads were probably cooked versions of a grain-paste, made from ground cereal grains and water, and may have been developed by accidental cooking or deliberate experimentation with water and grain flour. Descendants of these early breads are still commonly made from various grains worldwide, including the Mexican *tortillas,* Indian *chapatis, rotis and naans, and* Ethiopian *injera* (Jacob *et al.*, 1997).

The development of leavened bread can probably also be traced to prehistoric times. Yeast spores occur everywhere, including the surface of cereal grains, so any dough left to rest will become naturally leavened. Although leavening is likely to be of prehistoric origin, the earliest archaeological evidence is from ancient Egypt (Samuel, 2000). However, ancient Egyptian bread was made from emmer wheat and had a dense crumb (Samuel, 2000).

There were multiple sources of leavening available for early bread. Airborne yeasts could be harnessed by leaving uncooked dough exposed to air for some time before cooking. Gauls and Iberians used the foam skimmed from beer to produce a lighter kind of bread than other peoples (Tannahill, 1973). Parts of the ancient world that drank wine instead of beer used a paste composed of grape juice and flour that was allowed to begin fermenting, or wheat bran steeped in wine, as a source for yeast. The most common source of leavening was the use of starter. Even within antiquity there was a wide variety of breads available described by Greeks (Cunningham, 1990).

Within medieval Europe, bread served not only as a staple food but also as part of the table service (Trager, 1995). In the standard table setting of the day the trencher, a piece of stale bread served as an absorbent plate. At the completion of a meal the trencher could then be eaten, given to the poor, or fed to the dogs. It was not until the 1500s that trenchers made of wood started to replace the bread variety (Tannahill, 1973).

Otto Frederick Rohwedder is considered to be the father of sliced bread (Trager, 1995). In 1912 Rohwedder started work on inventing a machine that sliced bread, but bakeries were reluctant to use it since they were concerned that the sliced bread would go stale. It was not until 1928, when Rohwedder invented a machine that both sliced and wrapped the bread. A bakery in Chillicothe, Missouri was the first to use this machine to produce sliced bread (Trager, 1995).

For generation, white bread was considered the preferred bread of the rich while the poor ate dark bread. However, in most western societies, the connotations reversed in the late 20th century with dark bread becoming preferred as having superior nutritional value while white bread became associated with lower class ignorance of nutrition (Trager, 1995). Another major advance happened in 1961 with the development of the Chorleywood bread process, which used the intense mechanical working of dough to dramatically reduce the fermentation period and the time taken to produce a loaf. This process is now widely used around the world (Trager, 1995).

2.3 Ingredients used to make bread

There are two main ingredients in raised bread: flour and yeast. The other three ingredients are water, sweetening agent (sugar, honey, molasses, etc.) and salt. Also, herbs and raisins are used in herb and raisin breads, respectively. Most of the white breads have some milk and butter. Generally, flour, yeast, water, salt and sweetener are the basics (http://www.answers.com/topic/bread).

2.3.1 Yeast function

Yeast is a leavening agent during fermentation that helps the bread to rise. When warm water is added to the yeast, it begins to grow and as it grows, it attacks the sugar that is in the flour or added to the dough, thus producing carbon dioxide. This gas makes little bubbles that are trapped in the dough. Wheat flour has gluten, a protein, which makes the dough stretch instead of breaking when the bubbles are formed. It also affects the rheological properties of the dough through lowering pH by carbon dioxide production, evolution of alcohol and the mechanical effects of bubble expansion. The quantity used is inversely related to the duration of fermentation. Longer fermentation systems generally employ lower levels of yeast and also lower dough temperatures (Eliasson and Larsson, 1993).

2.3.2 Salt

Salt adds flavour and helps to control the rising of the bread by strengthening the gluten in the flour. It therefore slows down the rate of fermentation (Eliasson and Larsson, 1993).

2.3.3 Sweeteners

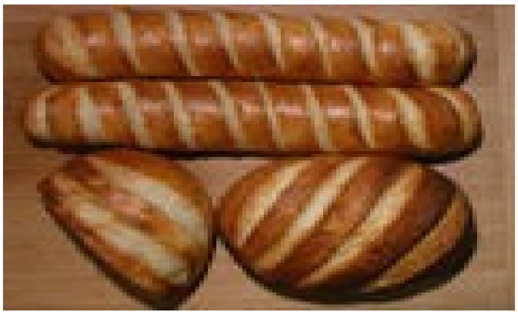
According to Eliasson and Larsson (1993), sweeteners add flavor, improve texture of the crumb, and give the yeast something to feed on. It provides a golden brown colour of the crust and helps to retain moisture in the crumb.

2.3.4 Water

Water helps to combine all the other ingredients, activate the yeast, and creates texture as it turns to steam during baking. It is necessary to hydrate the wheat proteins to form gluten as well as flour gums and damaged starch. It provides the matrix for chemical and biochemical reactions. Hard water is the best type of water that produces better quality bread (Eliasson and Larsson, 1993).

2.4 Common bread types

There are three general types of bread: leavened, flat and steamed. Although all three types are prepared from refined (or whole-meal) flour-water dough, which is viscoelastic and cohesive, each bread type differs from one another on specific end-product properties, processing conditions and grain quality needs (www.breadchef .com. au/ types-of-bread.html).. Another kind of bread classification is white bread, wheat bread, French bread, bagels, rye bread, or pita bread. Even crackers and muffins are considered as types of bread. Some breads have spices such as garlic and other breads are more bland, like white bread whereas others have lots of ingredients like cinnamon, raisin and cranberry. Some breads rise or are cooked for longer periods than others. For example, sourdough is baked for 25-30 minutes whereas the hearth loaf is baked for 45-50 minutes (http://www. Bread chef.com.au /types-of-bread.htm). Breads can be very different depending on ingredients and cooking time and even the same recipe can turn out quite differently from home to home or country to country depending on ovens, climate, and how it is made. The type and appearance of the mentioned bread is shown in Plate 1

(a)-European sweetbread **(b)-Four loaves**


(c) French bread **(d) Breads and bread rolls at a Bakery**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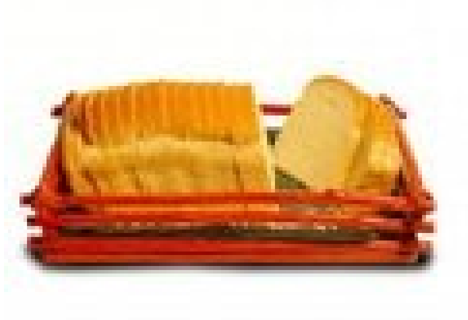

(e)–Tin Vienna bread **(f)–Pre-sliced bread**

Plate 1: Different kinds of bread

Source: (http://www.bread chef .com.au /types-of-bread.htm)

2.5 Composite bread

Although, bread is traditionally made from wheat flour, the use of composite flours containing wheat and other cereals or legumes has proven practical and is being utilized in many parts of the world to improve the nutritional and functional properties of flour.

Composite flour technology refers to the process of mixing wheat flour with cereals or legumes to make use of local raw materials to produce high quality food products in an economical way (Naureen, 2004). In many cases, this implies the partial substitution of wheat flour in a staple diet with other cereals or flour derived from legumes as means of diversifying and upgrading the local agricultural food products (Naureen, 2004).

Moreover, bread consumption is constantly increasing in many developing countries, Mozambique inclusive, which still depend mostly on imported wheat or wheat flour while they grow various staples such as starchy roots like cassava or cereals other than wheat. Efforts have been made to promote the use of composite flours from locally grown crops and high protein legumes that replaces a portion of wheat flour for use in bread, thereby decreasing the demand for imported wheat and producing protein enriched bread (Giami *et al*., 2004). Flours from other cereals such as rice, maize, sorghum and pearl millet and other crops like cassava, beans and plantain have been used as diluents for composite bread making (FAO, 1995). However, when non wheat flours are incorporated into the bread making formula such as in the preparation of composite flour bread, the dough and bread characteristics change depending on the level of wheat substitution. Non-wheat cereals such as corn flour lack the gluten that provides the viscoelastic properties that are characteristic to the whole wheat baked products (Giami *et al*., 2004).

2.5.1 Limitations of composite flour technology

As reported by CDI (1997) the main obstacles to the incorporation of local flours have been identified and are many. These limitations are discussed below

2.5.1.1 Lack of technology and knowledge on composite flour and bread

The technology of composite flour and bread is not advanced in Mozambique. There are few cereal technologists with few researches being done on the use of composite flour for bread making. Moreover, there is no sufficient dissemination of the results of research of results on the use of composite flour for bread making, from research institutions to the bakeries is only limited. Often the bakery owners and staff are illiterate with no enthusiasm for innovation. This limits the growth of this technology.

2.5.1.2 Low demand for products made from local cereals

Wheat baked products are mostly demanded by consumers as snacks and breakfast cereals than local cereal or tuber products which are considered as food for the poor. For example, wheat bread is preferred to cassava in breakfast. This might limit the advancement of composite flour using local cereals or roots/tubers unless people change their perspectives and food habits.

2.5.1.3 Poor quality of the composite flour bread and low acceptability

Bread from composite flour blends has relatively poor organoleptic and sensory qualities compared to those made using whole wheat, since their attributes are considered unacceptable by majority who are used to convectional breads. This may limit advancement of the technology and use of baked composite flour products.

2.5.1.4 Lack of motivation among bakery owners

According to CDI (1997) there is lack of motivation among bakery owners to use composite flour. This is likely to be associated to both technical and social reasons. In respective of the reason, this trend tends to affect popularization of composite flour.

2.5.2 Other cereals or crops used as diluents and their proportions

The degree of substitution tolerated by the wheat flour without affecting the bread loaf texture, volume and organoleptic characteristics depends on the quality of the wheat flour itself. Higher level of substitution is possible with hard than with soft wheat flour. It also depends on the composition and origin of the diluent flour, such as crude protein, fat, carbohydrate, ash, moisture content and the process used for bread making. When soybean is used in the formulation, the nutritional value is increased drastically, but there are also limits to this incorporation from organoleptic point of view. Other legumes including cowpea have similar advantages although inferior to soybean. Therefore, any blend with such legumes will always be advantageous to the ultimate consumer (Dhingra and Jood, 2002; Basman *et al*., 2003). According to FAO (1995), the crops that can be used as diluents to wheat flour include sorghum, millet, soybean, maize, cassava, cowpea and others.

2.5.2.1 Sorghum

Sorghum flour has been used as a diluent to wheat flour to meet the market demand. According to research conducted in the past, it has been indicated that breads made with composite flour of 70 percent wheat and 30 percent sorghum was acceptable (FAO, 1995). Also, it has been indicated that the bread can be made from sorghum–wheat composite flour in the proportions of 20:80 for wheat/sorghum (white and brown). However, sorghum alone is not considered as a bread making cereal because of the lack of gluten, but addition of 20-50% sorghum-wheat flour produces excellent bread (Hugo *et al*., 2003).

2.5.2.2 Millet

Millet flour can also be used as a diluent to wheat flour. It has been reported that bread could be produced from composite flour made by co-milling wheat with pearl or finger millets. The proportion of millet in the flour can be up to 15 percent. Bread containing 10 percent pearl millet flour had an excellent texture and flavour similar to that of whole-wheat bread (FAO, 1995).

2.5.2.3 Cassava

Bread could also be produced from wheat-cassava composite flour made by mixing cassava and wheat flours at a ratio of 10:90 (w/w) (Shittu *et al.*, 2005). This goes in line with research evidence by FIIRO (2005) which indicated that cassava flour can be incorporated into wheat flour for bread making at different levels of substitution, 10-15% cassava inclusion being most acceptable for bread making. A study by PAM (2005) revealed that blending cassava with wheat flour at 10 and 15% produced composite flour bread acceptable to Zambian consumers. This hints the possibility of reducing wheat importation to Mozambique if cassava is exploited at acceptable levels in bread making.

2.5.2.4 Soyabean

The use of soyabean in the production of composite flour and bread has been reported (Dhingra and Jood, 2002; Basman *et al*., 2003). It has been found out that breads produced with soyabean flour substitution, up to 15%, were nutritionally superior to the whole wheat flour. This is because, soyabean is an excellent source of protein (35-40%), hence soybean is the richest in food value of all plant foods consumed in the world (Kure *et al*., 1998). It is also rich in calcium, iron, phosphorus and vitamins and is the only source that contains all the essential amino acids (Ihekoronye and Ngoddy, 1985).

2.5.2.5 Maize

The maize composite flour can be prepared using 25 percent as maize flour mixed with 75 percent wheat without appreciable difference in the quality of the composite bread (Mejia, 2003)

2.5.2.6 Cowpea

Cowpea flour is used for fortifying cereals to improve the essential amino acid balance of baked food products especially in developing countries where cowpea is a cheap source of protein. The use of this crop as a food source has not been utilized fully, especially in developing countries. Germinated cowpea flour and fermented cowpea flour at levels of 5, 10, 15 and 20% have been used successfully in composite flour blends (Hallen and Ainsworth, 2004). The increase in cowpea content also changed farinograph and extensograph characteristics, mainly by increasing water absorption capacity. Incorporation of cowpea flour tend to exert a certain volume depressing effect on the bread and give a compact structure at higher substitution levels (Hállen *et al*., 2004). Increasing levels of cowpea flour in the blends also result in changed flour characteristics such as ash and protein content and colour changes.

2.6 Processing of composite flour for bread making

Composite flour can be processed by blending wheat flour with non-wheat-cereal flours at appropriate proportions. Flours are prepared at different unit operations, weighed and mixed. Alternatively, co-milling of wheat and non cereal grain can also be used for production of composite flour (Eliasson and Larsson, 1993).

2.7 Wheat flour composition

The chemical composition of wheat flour depends on the extraction rate. The compo sition of the flour differs from the composition of the grain. The lipid content of the whole kernel is in the range 2.8–3.2%, whereas the lipid content of the endosperm is 0.8–1.25%. The milling process is also a mixing process. After milling the different components come into interaction. The difference in composition due to the extraction rate causes variation in the flour properties and the most evident factor is the differences in baking performance. One reason for the deterioration of baking performance with increasing extraction rate is the redistribution of germ lipids. Another aspect of baking with whole meal flours is the deterioration in baking performance during storage time (Eliasson and Larsson, 1993).

2.8 Dough for bread making

To get the best results in baking there is an optimum level of water. During bread making the total water content changes. In proofing time there is an increase in water content. This slight increase in water is a result of fermentation and absorption of some moisture in the fermentation cabinet (Czuchajowska *et al.*, 1989). The optimum level of water addition can be determined by water absorption by the use of brabender farinograph. Both quantity and quality of proteins influence water absorption. Absorption increases linearly with the amount of protein, but the slope of the regression line depends on the wheat variety. The level of damaged starch also influences the optimum level of water absorption of the flour that increases when the level of damaged starch increases (Holas and Tripples, 1978).

2.9 Staling

When the loaf of bread is removed from the oven a series of changes start that lead to deterioration of the quality. This process includes all the processes that occur during storage except microbial spoilage. The consumer detects the staling by the changes in taste as well as in texture. The typical aroma of fresh bread is lost and a stale flavour develops with time. The crumb becomes dry and hard, whereas the crust becomes soft and leathery. We can reduce staling by keeping the bread at room temperature or freezing temperature and adding components like amylase, monoacyl lipids, triglycerides, sugar, amylases, protein, pentosans and salt at more than 2% as suggested by Eliasson and Larsson (1993).

2.10 Cowpeas in the world and Mozambique

2.10.1 Distribution area of cowpea production in Mozambique

Cowpea, (*Vigna unguiculata (L.) Walp*), is a grain legume grown in savanna regions of the tropics in West and Central African countries. Mozambique is probably one of the countries of origin of the cowpea (Bressani, 1985). Cowpea is rich in lysine and it can be used to enrich cereals and cassava but is limiting in sulphur amino acids, compared to other legumes and it has high methionine and tryptophan content (Singh and Jackai, 1985). In addition, it has the ability to tolerate drought, and it fixes atmospheric nitrogen, which allows it to grow on, and enrich poor soils.

In Mozambique, cowpea is well distributed except in Sofala province. It grows mainly in Inhambane, Gaza, Zambezia, Nampula, Cabo Delgado, Niassa and in Tete province region close to Zambezia province (Heemskerk, 1985). It was estimated that in 2004/05 Mozambique produced 201 000 tonnes of beans (Ministerio da Agricultura, 2006). FAO estimates that 3.3 million tones of cowpea dry grains were produced worldwide in 2000. Furthermore, it has been reported that Nigeria produced 2.1 million tones of cowpeas, making it the largest producer, followed by Niger (Singh and Jackai, 1985). However, although the trends of production of beans are rising, the yield per hectare is reported as being low (Ministerio da Agricultura, 2006). In Inharrime district at Inhambane province, the cultivated varieties are Nhangongori, Nhassengui, Malobvé, Chimbobo, Kau, Chinhembanhembani, IT18 and Mixed Brown (Ministerio da Agricultura, 2006). The trend in beans production and the cultivated area is shown in Fig.1. In 1998/99 season the yield was highest and the trend almost remained constant over subsequent years up to 2004/05. The area however, has shown some increase over the mentioned period.

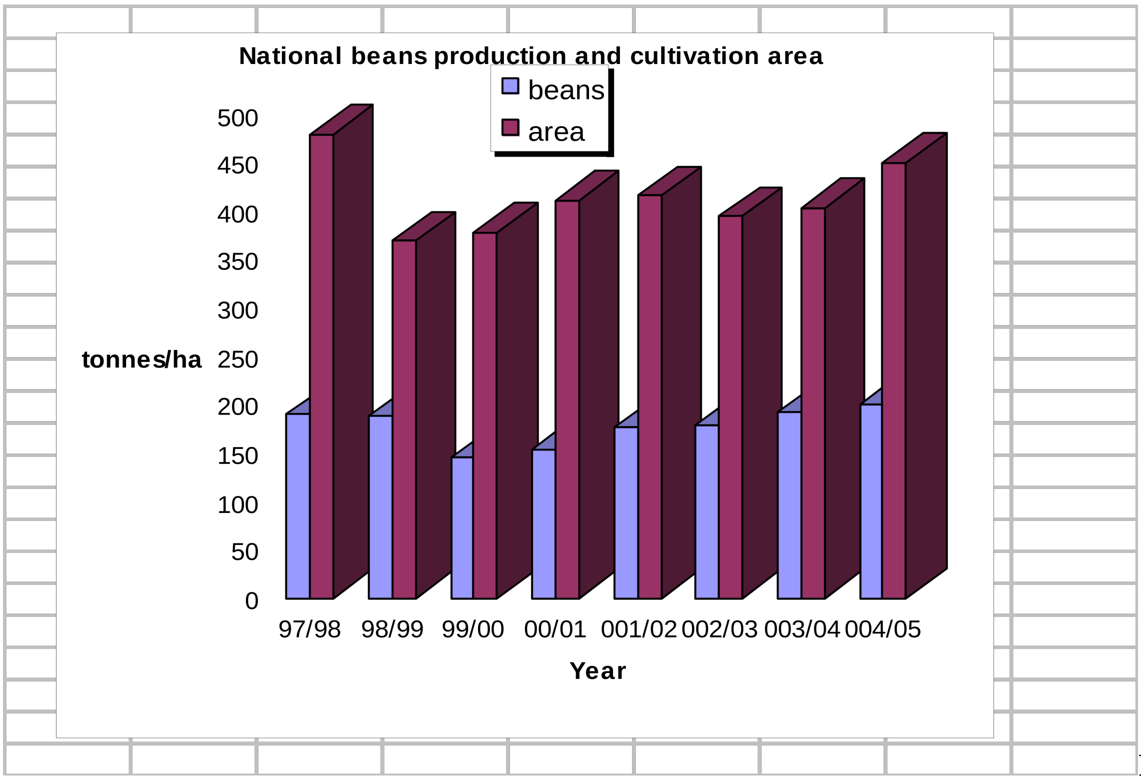

Figure 1: Production and cultivation area of beans in Mozambique

2.10.2 Nutritional value

The cowpea value lies in its high protein content, with relatively high lysine content making cowpea an excellent improver of the protein quality of cereal grains. The protein content range in g/100g is 24.1-25.4 and cowpea protein gives an apparent protein digestibility of 72% (Bressani, 1985) and 60-69% soluble carbohydrates (Ajibola *et al.*, 2003). Variability in protein content has been reported to be from 23 to 30% and is influenced by genotypes as well as by environmental factors (Singh and Rachie, 1985). The fat content range is 0.30 to 1.44% whereas the ash range is 3.68 to 4.36% (Hsieh, 1992).

2.10.3 Constraints in cowpea production

The major constraint limiting cowpea production in Mozambique includes insects and diseases like cowpea Aphid Mosaic Virus (CAMV) and Cowpea Golden Mosaic Virus (CGMV). The pests caused by insects include Aphids (*Aphis craccivora*), that feeds on foliage at seedling stage. Others include Thrips (*Megalurothrips sjostedti*), which feeds on foliage and pods, at seedling stage and legume pod borer (*Maruca testulalis*), that feeds on flower buds, flowers and green pods and Coreid bugs (*Clavigralla tomentosicollis C. horrida, Nezara viridula* and others species) which feed on green pods. Nematodes offers another constraints since they cause plant atrophy and root deformation. Another constraint is the prolonged long drought leading to crop failure (Singh and Jackai, 1985).

2.10.4 Importance and utilization of cowpeas in Mozambique

In Mozambique, cowpea is an important source of protein and energy. Cowpeas are widely consumed in different forms in this country. The dried grains and fresh green pods are eaten in many ways. For example cowpea grain is eaten as *tihove* (a mixture of cooked maize, cowpea grain, peanut flour and salt), *Chiguinha* (a thick paste made from a mixture of cooked cowpea grains, cassava pieces, peanut flour, coconut milk and any sort of vegetable leaves), cowpea curry cooked using cowpea grains, with fried onions, tomatoes, salt and meat. Also, fish or shrimps and coconut milk or peanut flour can be added. Others are cowpea curry made using dry grain cooked with peanut flour, coconut milk and salt. E*cute* which is a soft paste made from decorticated cowpea grains, flavored with fried onions, tomatoes in which coconut milk can also be added. Furthermore, another type of curry is made using cowpea mixed with peanut flour, onions, tomatoes, coconut milk and shrimps or curry powder. Also, *nhangana* comprising of cowpea fresh leaves, young pods broken in quarters, dried or fresh shrimps or any other sea food cooked with onions, tomatoes, salt, coconut milk and peanut flour and *nculułu* that is cooked using fresh pods with salt are common. There are some Indian products like *badgias* which are fried pieces of a paste made with cowpea flour, water, salt, onion and garlic. Another cowpea food is *dahl* that is the same as ecute, but with more pieces. *Kigiri* is made up with rice and decorticated cowpea grains, cooked with butter, coconut milk and salt and as curry cooked with peanuts and salt (Pelembe, (2001). The nutrient content of wheat, cassava and cowpea is shown in the Table 1.

Table 1: Nutrient composition of wheat, cassava and cowpea flours

Type of flour	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Dry mater (%)	Moisture (%)	Carbohydrate (%)
Wheat flour	4.5-15.0	1.50-9.72	1.90-13.2	0.40-2.60	86.0–91.0	9.0–14.0	51.8-71.9
Cassava flour	0.5-2.0	0.17-0.50	0.43-1.40	0.84-2.41	86.0-91.0	9.0–14.0	20.0-34.7
Cowpea flour	22.0–30.0	0.30-1.44	6.0–10.57	3.68-4.360	81.0–91.0	9.0–14.0	60.0-69.0

The source: Bradbury and Holloway (1988), Eliasson and Larsson, (1993); Carnovale *et al.*, (1990) and Summerfield and Bunting (1990)

2.11 Cassava in the world and Mozambique

2.11.1 Introduction of cassava plant

Cassava is a tropical crop that is rarely produced by large plantations and industrial organizations. As a result, it has received little attention from highly qualified scientists and technologists (Nestel and Cock, 1980). Cassava originated from America and it was introduced to Mozambique by Portuguese in the 17 century as a way to feed the slaves (www.iita.org/cms/details/trn_mat/irg49/irg494.html). Cassava is adapted to the zone within latitudes 30° North and South of the equator, at elevations of not more than 2 000 m above sea level, in temperatures ranging from 18 to 25°C, rainfall of 50 to 5 000 mm annually, and is tolerant to poor soils with pH from 4 to 9.0 (Okigbo, 2008). This plant yields well on marginal soils without excessive use of inputs (Phuc *et al*., 2000). It is cultivated mainly in Africa including Mozambique and Tanzania as a subsistence food crop, but a considerable part of the world production is used as animal feed and for industrial use. Many farmers increasingly grow it as a cash crop (Dgis, 1991). The plant flourishes on soils so poor and under attacks of severe drought and pests, where all other crops would perish.

2.11.2 Kinds of cassava

There are three kinds of cassava which are innocuous with less than 50 mg HCN/kg of fresh, peeled root; moderately poisonous with 50-100 mg HCN/kg of fresh peeled root and the dangerously poisonous with over 100 mg HCN/kg (http://www .unu .edu/ unup res s/food/8F024e/8F024E01).

2.11.3 Cassava and its processing methods in the world

Traditional processing methods vary immensely from region to region. It includes peeling, soaking, chipping, grating, pressing, milling, drying, stacking and fermentation. Most of these being adaptations of yam-processing techniques (Hahn, 1989). Cassava is processed in the wet or dry form to starch or flour or to paste-like foods. In wet processing procedures, the root may be fermented prior to processing (Hahn, 1989).

2.11.4 Cassava flour production and utilization

Cassava flour is the product obtained from milling the dried, raw root (FAO, 1998) and it has also been defined as the starchy substance extracted from the root of the cassava plant (Herbst, 1997). The root may be chipped or sliced, dried and then milled into flour, using roller mills, ball mills or hammer mills (Badrie and Mellowes, 1992; De Floor and Delcour, 1993). Traditional method of pounding can also be used. The root is sometimes fermented prior to milling. Parboiling of tapioca root chips prior to milling into flour has been suggested to improve the pasting properties of cassava flour (Raja and Ramakrishna, 1990). Cassava flour is also used as a thickener in soups among other uses (Lorraine and Fatimah, 2000). There is therefore need to mechanize the processing of cassava especially into products such as chips, pellets, flour, pancakes, adhesives, alcohol, and starch, which are vital raw materials in the livestock, feed, alcohol/ethanol, textile, confectionery, wood, food and soft drinks industries. These products could be traded in the international market (Abolaji *et al.*, 2007)

2.11.5 Distribution of cassava production in Mozambique

Cassava in Mozambique is almost produced all over the country. It is a source of income and a staple food in some provinces. Cassava production in Mozambique is estimated to occupy one-third of the total production area. In 2004/05 the global production was 6.6 millions tonnes of cassava. Cassava grows in the whole of Mozambique, but the biggest producing provinces are Nampula, Zambezia, Cabo Delgado, Inhambane and Gaze and yield is estimated at 4–6 tonnes/hectare (SARRNET, 2003). According to the available projections, the trend of cassava production is poised to rise (Ministerio da Agricultura, 2006). In Inharrime district of Inhambane province mainly sweet varieties such as Tchicela ni Tchai, Gorugoru, Nalayvatane, Chinhembué and Munhaça are grown. Also, bitter varieties such as Kusse and Nhambatsana are cultivated. A new variety of cassava has been released recently in Mozambique (IIAM, 2008). It is disease resistant and has high yield capacity of 20 tonnes per hectare compared to the old variety, which has yield capacity of 10.4 tones per hectare (IIAM, 2008). The national cassava production and area under cultivation in Mozambique are as shown in Fig. 2 for the period 1997/98 through to 2004/05. Yield increased although the trend of area under cultivation seem to be somehow stagnated.

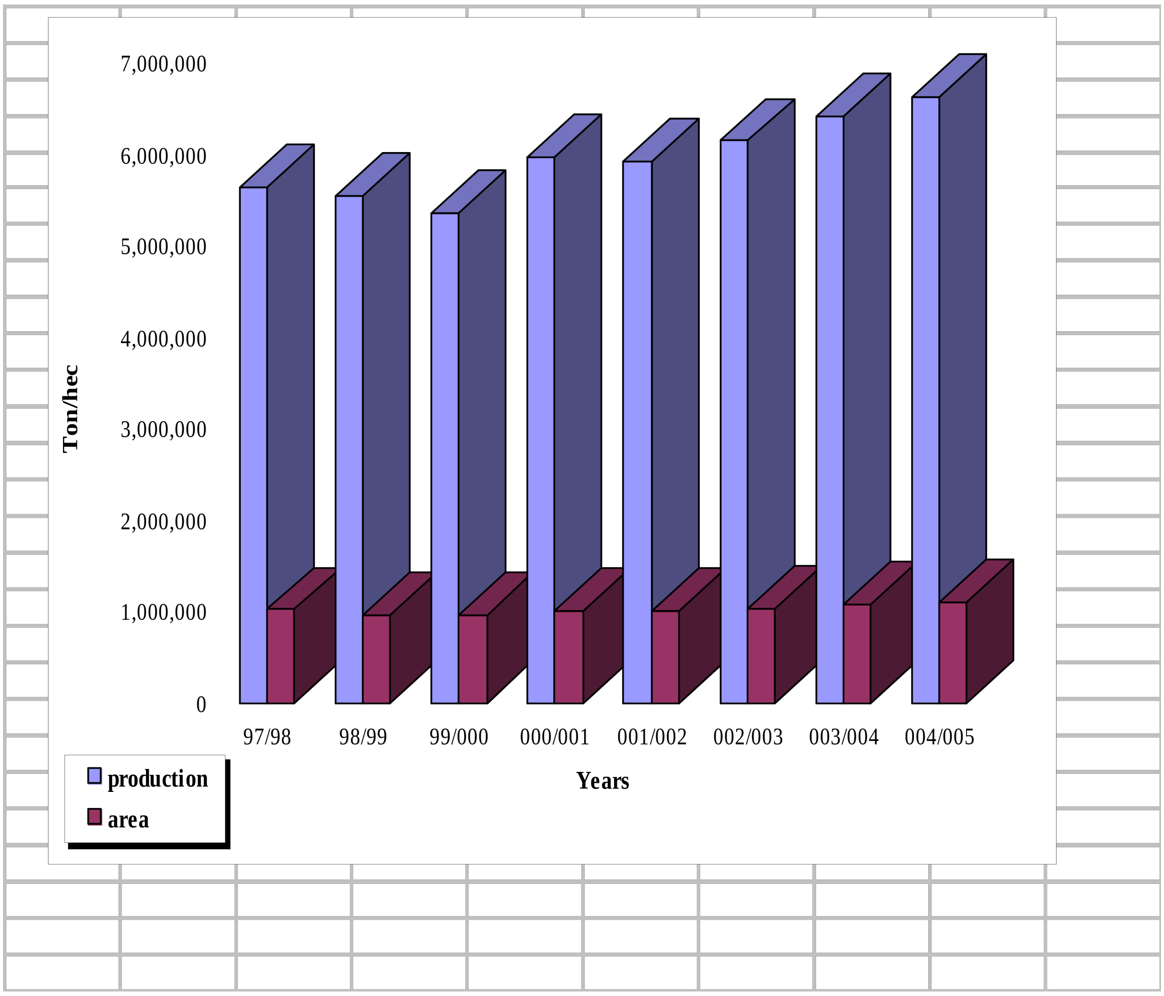

Figure 2: National cassava production and cultivation area in Mozambique

2.11.6 Cassava production constraints

One of the major cassava production constraints is the cassava mosaic disease caused by several geminiviruses and is transmitted by white flies *Bemisia tabaci*. Is pandemic in Mozambique, reduce yield and put farmers at risk. It is causes significant food losses every year. Cassava mosaic desease resistant varieties are needed wherever cassava is grown (http://www.iia.msu.edu/project_sabp.html).

Brown streak virus has been found to be critically important in northern provinces of Mozambique (Chrissie, 2006). Another problem includes mites and bacterial blight. More widespread, participatory evaluation of resistant materials, as well as more decentralized breeding programmes, are required (Chrissie, 2006).

Cassava Brown Streak Virus disease (CBSD) is caused by Cassava Brown Streak Virus (CBSV) from the family Potyviridae and genus *Ipomovirus*. CBSV particles are sub-microscopic flexuous rods, approximately 750nm in length, which can only be viewed with an electron microscope. The genome comprises of a single-strand of RNA, enclosed within a protein coat. Symptoms are most pronounced during the dry season and above ground symptoms may not be apparent during periods of wet weather. Economic losses result both from damage to the above ground plant parts associated with dieback and from the spoilage of roots resulting from dry necrotic rot. Total crop loss may occur where susceptible varieties are grown in areas where CBSD is prevalent. The disease is the most economically important constraint to cassava production in northern Mozambique although no quantitative assessments have been made of these losses (http:/www. /saspp. org/content/view/60/11/).

2.11.7 Importance and cassava utilization in Mozambique

In Mozambique, cassava is a very important staple food. Among the regions where people are depending on it as a food crop and as a source of income, cassava is consumed as main staple, secondary or as supplementary food. It has been an important crop in its contribution to the food supply for Mozambique, as corn, rice and potatoes have been elsewhere. It is eaten as *Chiguinha*, (cooked fresh manioc with salt and vegetables) as bread when it is boiled, also is eaten raw or as roasted cassava, fried with onions and tomatoes, chips, as a porridge, and thick porridge. People from Inhambane province make *rali* which is peeled cassava that is grated, soaked during 2 or 4 days, then roasted. *Rali* can substitute bread or rice and last for more than one years (Tivana and Bvochora, 2005). Also, it is eaten as sweet after cooking in small pieces with coconut milk and sugar with added spices).

2.11.8 Nutritional value

The nutrient composition of cassava varies from place to place depending on climate, type of soil, crop variety and other factors. Cassava is a high energy producing root crop consisting mainly of carbohydrates (FAO, 1989). The fresh roots have 30–40 g/100g dry matter of protein, fat, fiber and carbohydrate. But the protein content is very low at 1.2g/100g dry solid and the amino acid profile of the cassava root is very low in some essential amino acids, particularly lysine, methionine and tryptophan (Okigbo, 2008). Also, the amino acid is low in phenylalanine and tyrosine but rich in arginine (Oyenuga, 1972). The peel of cassava roots contains slightly more protein than is found in the flesh. Therefore, peeling results in loss of part of the valuable protein component of the root. However, it has been observed that fermentation of the roots results in protein enrichment (Okigbo, 2008). The fat content for cassava is also low, between 0.2-0.5g/100g dry solids (Cook, 1985). Most of carbohydrate fraction is starch, which makes up 20-25 % of the fresh root. Among the minerals in the root, phosphorus and iron predominate but also there is a small amount of calcium. Cassava is relatively rich in vitamin C ranging from 34-36mg/100g dry solids, and traces of niacin and vitamin A, B_1 and B_2 but the amounts of thiamine and riboflavin are negligible (Oyenuga, 1972). Large proportions of these nutrients are lost during processing and thus should be taken into account in cassava processing in order to retain as much as possible of these nutrients.

Cassava leaves are richer in proteins than the roots. Although the leaves contain far less methionine than the roots, the levels of all other essential amino acids exceed the FAO's recommended reference protein intake. For this reason, cassava leaf protein is claimed to be superior to soybean protein. Supplementation of Cassava products such as leaf-meal with methionine or any other of the nutrients it lacks serves to improve its biological value (Okigbo, 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area description

The study was carried out in Morogoro Urban District, Tanzania and Inharime District, Mozambique. Morogoro urban is located in eastern part of Tanzania, 200 km from Dar-es-Salaam and Inharrime District in Mozambique is located in sourthern part of Mozambique. Inharrime was chosen due to its high number of cassava growers, popularity of cassava as the main staple food and the importance of cassava as a major source of income generation.

3.2 Source of samples

The samples used in this study included four varieties of cassava, one variety of cowpea and locally supplied wheat flour from Tanzania and Mozambique.

3.2.1 Cassava

Cassava roots used in this study were freshly harvested. In Morogoro, Tanzania four varieties of cassava namely: *Kiroba*; *Mzuri.Kwao*; *Mumba* and *Kigoma* were processed into cassava flour.

In Mozambique, cassava roots were freshly harvested in Inharrime District. These included four varieties of cassava namely: *Chinhembué*; *Nhambatsana*; *Kussé* and *Tchicela ni Tchai*.

3.2.2 Cowpea

The cowpea grains were supplied from the local market from each country. In Tanzania, one variety of cowpea known as *Horizontal* was used and in Mozambique a *Mixed Brown* variety was obtained from the local market was used.

3.2.3 Wheat flour

The wheat flour was obtained from the local suppliers in the market and it was sourced from the same dealer in each country. In Morogoro, Tanzania, special bakers flour produced and packaged by Salim Bakhresa & Co. Ltd (AZAM) Dar-es-Salaam was used. In Maputo, Mozambique, the used flour was obtained from Farinha para Pão Babita, Sociedade Commercial e Industrial de Moagem LDA based in Machava, Mozambique.

3.3 Methods

3.3.1 Preparation of cassava flour in Morogoro

Four varieties of fresh cassava roots, weighing 100 kg each were separately peeled and washed in clean water. After peeling 80 kg of peeled cassava was obtained. Thereafter 40 kg of peeled cassava was cut into 5-10 cm thick slices and dried in a cabinet type solar drier. The remaining 40 kg of peeled cassava was soaked for 2 days in 50 litres of water, placed in plastic containers at ambient temperature with temperature being measured on daily basis using a liquid in glass thermometer. The soaked cassava was then washed, cut into 5-10 cm thick slices and dried in a cabinet solar drier. Fibre and coarse materials were removed before cutting the slices into small pieces. The small pieces were dried for two or three days and then milled into flour using a maize milling machine. After that the flour was dried for 4 hours, sieved using a 0.150 mm sieve, packed in clean containers and stored in a cool place. The process flow chart for each of the four cassava varieties is shown in Fig. 3.

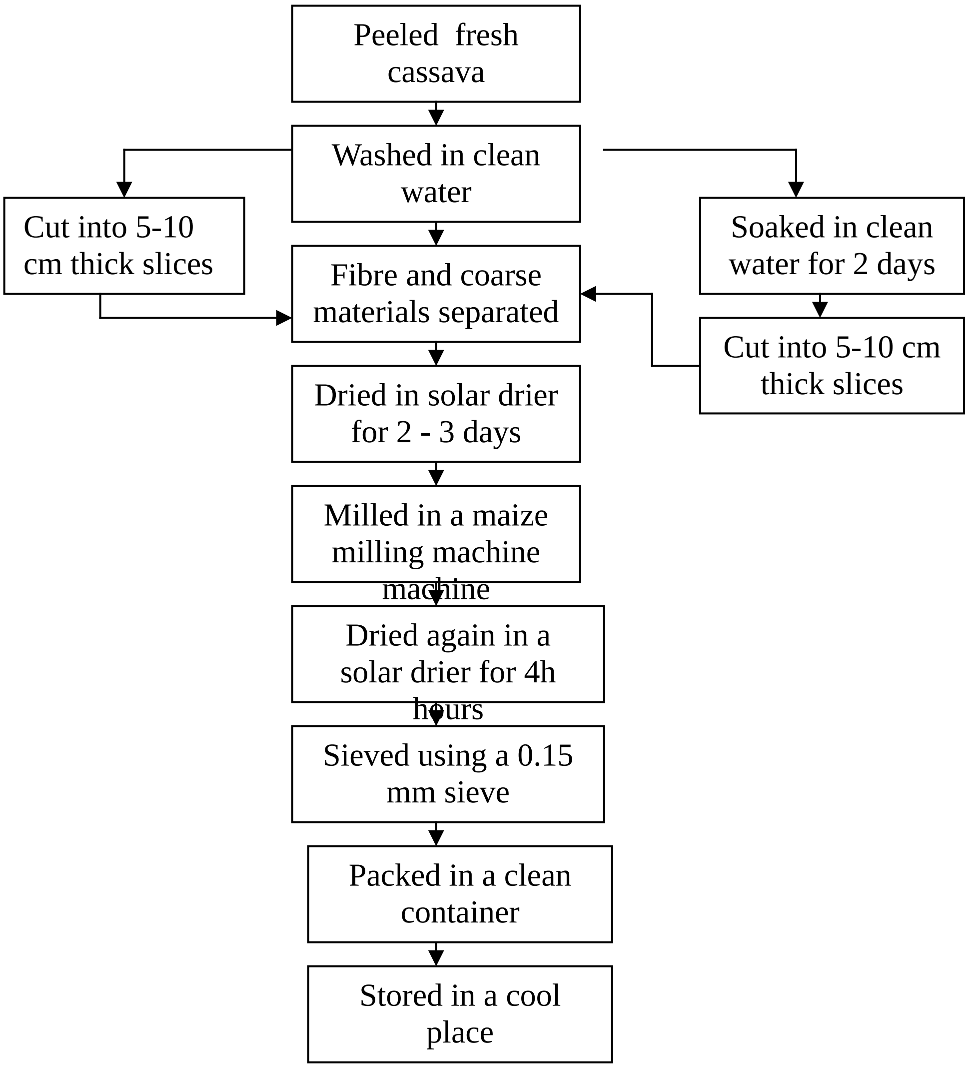

Figure 3: Cassava flour production

3.3.2 Preparation of cowpea flour

About 30 kg of cowpea were sorted, washed and soaked in 80 litres of water for 12 hours, dried for 2-3 days and milled using a maize milling machine. The resulting flour was dried for four hours, sieved using a 0.150 mm sieve, packed in clean containers and stored in a cool place. This approach was used in both countries. The process for preparation of the flours was done as shown in Fig. 4.

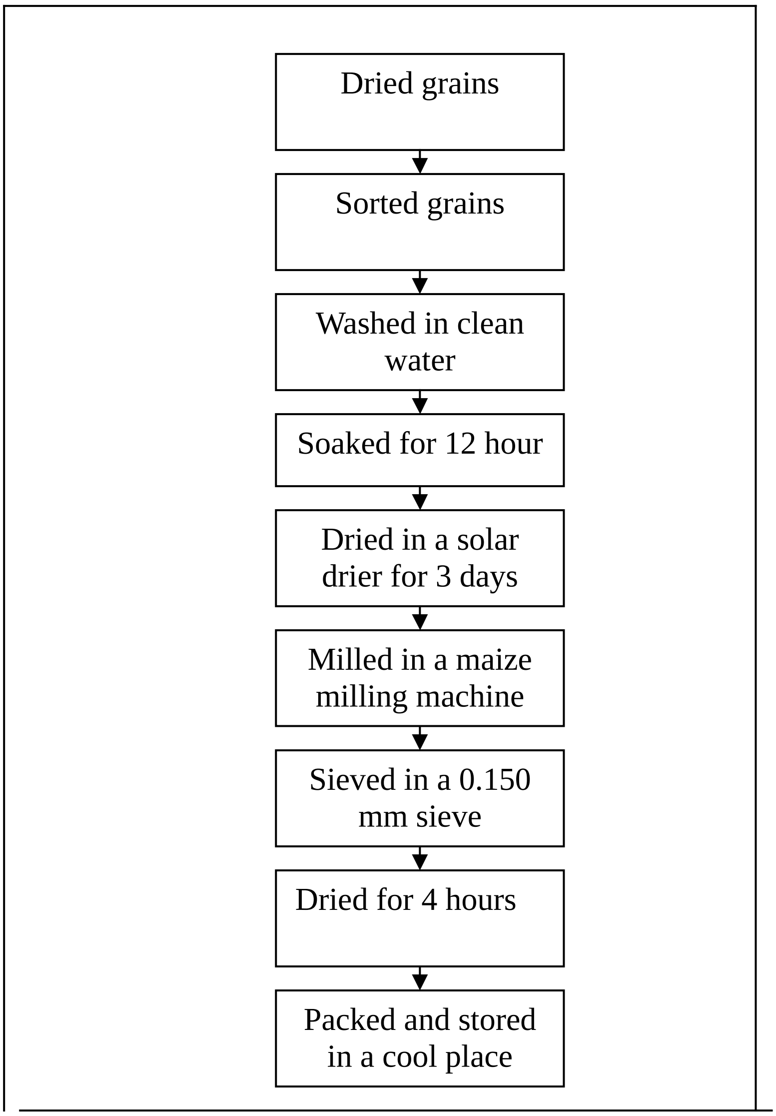

Figure 4: Cowpea flour production flow diagram

3.3.3. Proportion of flours in different formulation for the composite bread

A total of 8 flour mixtures were used. Four flour mixtures were made of blends of wheat-cowpea–non-soaked-cassava. The remaining four flour mixtures were blended using wheat-cowpea- soaked-cassava. Each flour mixture had 16 formulations as shown in Table 2. The dough prepared from each formula was replicated 3 times.

Table 2: Composite flour bread formulations

Formulation	Wheat	Cassava	Cowpea
Formula 1	100	0	0
Formula 2	95	5	0
Formula 3	95	0	5
Formula 4	90	0	10
Formula 5	90	10	0
Formula 6	90	5	5
Formula 7	85	0	15
Formula 8	85	15	0
Formula 9	85	5	10
Formula 10	85	10	5
Formula 11	80	0	20
Formula 12	80	20	0
Formula 13	80	5	15
Formula 14	80	15	5
Formula 15	80	10	10
Formula 16	70	0	30

3.3.3 Preparation of cassava based bread

3.3.3.1 Experiments carried out in Morogoro, Tanzania

The 16 formulations were baked using the straight dough method as suggested by Chuahan *et al*. (1992). The ingredients for these formulations were mixed together in right proportions using a mixing bowl. The dough was allowed to rise for one hour in a moist warm place, then it was knocked back to push out the gas. After that it was cut into small pieces weighing 250 g and allowed to rise in tins for 1 hour. The baking was done at 180–240°C as explained by Hoseney (1994). For each formula 500g of hard wheat were used, 360 ml of water, 10 g of yeast, 5 g of salt, 20g of shortening and 30g of sugar. The ingredients were weighed on a balance after zeroing. Water temperature was adjusted to 50 °C and yeast was added to part of the water (50ml). This was followed by putting sugar, salt and remaining water into the mixing bowl and 20g of shortening were added and then mixed thoroughly. The obtained dough was turned in the bowl and kneaded by hands for about 10 minutes and weighed. The hands were washed and smeared with cooking oil for kneading. The ball of dough was rolled in an oiled bowl that was used for kneading. Each dough mixture was covered by a muslin cloth and was taken out to sunshine in order to allow the dough to rise.

3.3.3.2 Bread making in Maputo, Mozambique

The major bread type in Mozambique is the pan type or French type bread, which lasts a day and people buy it daily. For each formulation of composite bread 1 kg of composite flour was weighed, mixed with 700 ml of water, 10 g of salt and 15 g of fresh yeast. After proper mixing, it was allowed to rise for 45 or 60 minutes depending on the ambient temperature (http://www.baking911 .com/bread /French .htm). The dough was knocked back to push out the gas, weighed and formatted in bread shape and allowed to proof for 20 to 30 minutes. The final rising was done until the dough was doubled in volume. After rising a shallow cut along the top of the loaf was made using a sharp knife. The purpose of cutting the loaf was to let steam escape and prevent the loaf from getting wild cracks during baking. The oven used for baking was preheated prior to baking (http://www.baking 911 bread/French), the bread was baked in the oven for 25 to 30 minutes at 195 to 250ºC. All the formulations were blended separately and breads for control and composite flours were baked in four replicates.

3.3.4 Sensory evaluation

In Tanzania, the samples and the control were given to 30 semi-trained panelists mainly students and staff of Sokoine University of Agriculture, who were familiar with the sensory attributes. The age of the panelists ranged from 20 to 56 years old.

In Mozambique, the panelists were made up of peasants from Josina Machel Cooperative and local people from Inharrime district in Nhanombe place. The age of the panelists ranged from 18 to 64 years old.

A 5 point hedonic scale was used to measure the degree of preference of the samples. The samples were presented in identical containers coded with 3 digit random numbers. The samples were evaluated in batches by the same panelist. The degree of preference was converted into numerical scores ranging from 1 to 5, with 1 as the lowest and 5 the highest score. Necessary precautions were taken to prevent the carry over flavour during the tasting by ensuaring that the panelists rinsed their mouths with water after tasting a sample.

3.3.5 Proximate analysis

Chemical analysis was carried out using the Official Methods of Analysis (AOAC, 1995). Moisture content was determined using oven drying method at 105ºC overnight for fresh cassava and 2 hours for bread and flours. Ash was determined using furnace at 500–600ºC for 5–6 h. Protein content was determined by Kjeldahl procedure, whereas fat content was obtained by Soxhlet extraction method using petroleum ether (Pomeranz and Meloan 1992). Crude fibre was determined using light petroleum, boiling in diluted sulphuric acid, diluted NaOH, diluted HCl, alcohol and ether. The carbohydrates were determined by difference after determination of other food components. Cyanogens were determined using Edward Ticks method, as explained by Edward, (1974).

3.3.5.1 Moisture content

The moisture content was obtained by weighing the sample placed in pre-weighed dishes using analytical balance. This was followed by placing samples in an oven, set at 100–105ºC overnight for fresh cassava and 2 hours for breads. Samples were then taken out from the oven and put in a dessicator, for 30 min to cool, and then weighed. The procedure was repeated until the difference between two successive weighings were less than 1 mg. The moisture content was calculated using the formula:

$$\% \ moisture = \frac{M_{initial} - M_{dried}}{M_{initial}} \times 100$$

3.3.5.2 Bread moisture content at Sokoine University of Agriculture

At Sokoine University of Agriculture, the bread was baked at a laboratory scale and the moisture content of the loaf was determined using only the crumb because the crust is not much dried like the pan bread and the crumb is very wide compared with the crust. The bread was dried in the oven for two hours and repeated until the weight was constant.

3.3.5.3 Bread moisture content in Novela Bakery (Maputo)

In Novela bakery the pan was baked at industrial scale. The moisture was determined by measuring the moisture content of the crumb and crust separately.

3.3.5.4 Crude protein content

The protein determination was done using the Kjeldahl method, where samples were digested in sulphuric acid (H_2SO_4), using $CuSO_4.5H_20$ as catalyst with K_2SO_4 as boiling point elevator, to release nitrogen from protein and retain nitrogen as ammonium salt. Concentrated sodium hydroxide (NaOH) was added to release the ammonia (NH_3), which was distilled, collected in boric acid (H_3BO_3) solution and titrated (Pomeranz and Meloan 1992). The protein recovery verification was checked using 0.12 g ammonium sulfate and 0.85 sucrose per flask and all reagents were added as done in sample preparation. The recoveries were 99% with the protein content being calculated as indicated in the formula:

$$\% \ Nitrogen = \frac{1.4007 \times (ml \ HCl_{sample} - ml \ HCl_{blank}) \times normality \ HCl)}{g_{sample}}$$

The result was multiplied by factor 6.25 to calculate the percent of protein, giving protein on a total nitrogen basis (Barbano *et al.*, 1990).

3.3.5.5 Ash content

The ash content of the bread was determined by weighing 2 g of sample then putting the sample in a pre-weighed moisture dish before drying in the oven at 100-105 ^{o}C overnight. Afterwards, samples were placed in a dessicator and left for 20–30 minutes to cool, then weighed again to determine the moisture content. After that it was put in a muffle furnace at 450^{o}C and left overnight. Next day, samples were removed and cooled in a dessicator and then weighed again. The results, were calculated and expressed on dry matter basis (Pomeranz and Meloan 1992).

3.3.5.6 Crude fat

Crude fat content was determined using the Soxhlet method for fat extraction as explained by AOAC (1995) and using 5 g of sample. The fat was extracted using petroleum spirit, then followed by determinination of the weight of the fat recovered. The sample was contained in a porous thimble that allows the solvent to completely cover the sample. Fat content was calculated as shown in the formula as explained by Pomeranz and Meloan (1992)

$$\%\ fat = \frac{weight\ of\ \ fat\ (g)}{weight\ of\ \ dry\ sample(g)} \times 100$$

3.3.5.7 Crude fibre

The crude fibre was determined using the method explained by AOAC (1995) whereby the samples (2.5g each) was transferred into a beaker and then 200 ml of boiling 0.2553 H_2SO_4 was added and connected to the digestion apparatus and boiled for 30 minutes. This was followed by filtration using filtering cloth and then washing with hot water until it was free from acid. The residue on the cloth was transferred into a flask with 200 ml of boiling 0.30N solution that was connected to the digestion apparatus and boiled for further 30 minutes, filtered through gooch crucible and washed until it was free from alkali and then washed with 10 ml of alcohol and dried at 100–110°C in an oven for about 2 hours. It was then cooled at room temperature in a desiccator and weighed. The process was repeated until the difference between two successive weighings was less than 1 mg. The contents of the crucible were incinerated in an muffle furnace at 600±20°C for about 30 minutes and cooled to room temperature in a desiccator and weighed. The process was repeated until the difference between two successive weighings was less than 1 mg. The amount of crude fibre was calculated as the difference between the weight of crucible and contents after drying and the weight of crucible and ash after incinerating over the sample weight and expressed in percentage (http://www.starch. dk/isi/ metho ds/crude fibre.htm). The crude fibre was calculated by the formula:

$$\%\ Crude\ \ fibre = \frac{w_1 - w_2}{w} \times 100$$

where: w-weight of sample,

w_1 - weight of crucible and contents after drying (g) and

w_2 - weight of crucible and ash after incinerating (g)

3.3.5.8 Carbohydrates

The carbohydrates were calculated by difference using the formula:

$$[100 - (moisture + fat + fibre + ash + protein)]$$

3.3.6 Bread weights

The bread weights were measured immediately after baking and allowing the bread to cool, then breads were weighed again and recorded.

3.3.7 Loaf volume determination

The bread volume was determined by filling up a container of 2.150 litres of capacity with finger millet, then part of finger millet from the container was replaced by bread and filled up completely with finger millet. The remaining finger millet was corresponding to the bread volume as explained by Esteller and Lannes (2005) and Ayo (2003).

3.3.8 Specific volume

The specific volume was measured by dividing the loaf volume by the bread weight as specified by Esteller and Lannes, (2005).

3.3.9 Baking losses

Baking losses are the losses showed by the difference between dough weight and the bread weight and are calculated by the Equation 6 formula as explained by Kussaga (2007).

$$\%\ losses = \frac{(weight\ of\ \ dough\ before\ baking) - (weight\ of\ \ product\ \ after\ baking)}{weight\ of\ \ dough\ before\ baking} \times 100$$

3.3.10 Cyanogen determination

A thin (1-2 mm thick) section of the clean cassava root was cut about halfway along the length of the root. The peel was removed and a section was cut and its weight adjusted to 100 mg by cutting off small pieces, weighing and placing in a small sample bottle. A sample of 0.5 ml of distilled water was poured and a yellow picrate paper attached to a plastic strip was placed into the small bottle and it was not allowed to touch the liquid. Immediately, the small bottle was closed with a screw capped lid. A sample without cassava root was prepared to serve as a blank. The small bottles were allowed to stand for 16-24 hours at room temperature (25-37ºC). After that the bottles were opened and the colour of the picrate paper was matched against the colour chart and the total cyanogens read in ppm. The blank was also checked to serve as a control which gave the expected values (Bradbury *et al.*, 1999).

3.3.11 Shelf life of formulated breads

In each formulation three breads were exposed to the ambient, and other three were kept in a plastic bag. The bread was checked on daily basis and recorded until it became stale. The measurement of shelf life was done for pan type bread in Maputo. During this period samples were analyzed by visual inspection if it was undergoing staling, because bread mould is relatively harmless (http://www.msed.iit. edu/ids/ curriculum/biology / model_ lessons/ Unit_6_ BreadMold).

3.3.12 Quality Assurance

For preventing contamination, all potential hazards were controlled, to assure safe and acceptable products. For quality assurance of the bread and from the fact that cassava contains hydrogen cyanide that arises from hydrolysis of cyanogenic glycosides, the flour for bread making was obtained from properly processed cassava. The flour was dried until it was of low moisture in the range 9 to 13%.

3.3.13 Statistical analysis

The data was verified, compiled, coded and summarized before analysis using (SPSS) computer program, version 11.5. The raw data was subjected to Analysis of Variance to establish if there were statistical differences in loaf volume, baking losses, specific volume and sensory evaluation.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Cassava processing

4.1.1 Cassava losses

During cassava flour processing it was found that total material losses of 75% occurred. The peels were around 20% whereas water content was 55%. Cassava flour was almost 25% of the unpeeled cassava. All used cassava varieties were moderately bitter with cyanogens between 50 and 100 mg HCN/kg of fresh peeled root. In Inharrime district some varieties were bitter with high amount of cyanide, but the processing was effective due to soaking. Table 3 shows the losses in cassava flour processing and the cyanogenic glucoside content of the varieties collected in Tanzania and Mozambique.

Table 3: Losses during cassava flour processing at Sokoine University of Agriculture in Tanzania and in Inharrime district, in Mozambique

Cassava varieties	Unpeeled cassava (Kg)	Cassava flour (Kg)	% loss in weight (kg)	Cyanogens (ppm)
Tanzanian varieties				
Mzuri.Kwao	100	25	75.0	80
Mumba	80	18	77.5	80
Kigoma	100	24	76.0	70
Mozambican varieties				
Chinhembué	80	22	72.5	80
Kusse	81	18	77.8	120
Nhambatsana	80	24	70	90
Tchicela ni Tchai	43	11	74.4	70.0

The Mozambican varieties had more cyanide than the Tanzanian varieties. Whereas Tanzanian varieties ranged from 70 to 80 ppm, those from Mozambique had between 80 and 120 ppm of hydrogen cyanide content.

4.1.2 Soaking process

One of the alternative methods of cassava processing was soaking in clean water. It was observed that, the water temperature raised from 24°C in the first day of soaking up to 27°C in the third day, except for Mumba variety where temperature rose to 28°C (Table 4). The main explanation could be that the fermentation rate was influenced by variety or level of contamination by fermenting organisms. However, in Inharrime district in Mozambique, the opposite occurred (Table 4).

Table 4: Temperature variation during cassava soaking in Tanzania and Mozambique

Cassava varieties	Day 1		Day 2		Day 3	
	R. temp. (°C)	S. Water temp. (°C)	R. temp. (°C)	S. Water temp. (°C)	R. temp. (°C)	S. Water temp. (°C)
Tanzanian varieties						
Kiroba	28.0	24.0	28.0	25.0	32.0	26.5
Mzuri Kwao	29.5	24.0	29.0	26.0	30.1	26.7
Mumba	31.0	24.0	33.0	26.3	31.5	28.0
Kigoma	30.0	23.8	33.0	26.5	29.2	27.0
Mozambican varieties						
Chinhembué	30.0	28.8	29.0	29.0	27.4	26.8
Kusse	29.4	28.9	28.1	26.7	24.0	25.5
Nhambatsana	29.4	28.9	28.1	26.3	24.0	25.1
Tchicela ni tchai	29.4	28.9	29	26.8	24.2	25.3

Instead of the soaking water temperature rising, it decreased. This may be due to the fact that soaking water was harvested from rain and was collected in a concrete reservoir. This temperature ranged from 25.5 to 28.9°C on the third day of soaking. In Mozambique pH measurement revealed pH of 7 in the first day decreasing to 4 for *Nhambatsana* and *Tchicela ni Ttchai* varieties and 5 for *Kusse* and *Chinhembué* varieties.

4.1.3 Cassava, cowpea and wheat flour proximate analysis

Proximate analyses showed that for Tanzanian cassava samples moisture content ranged from 57.3 to 61.0%, while moisture content of Mozambican cassava ranged from 63.5 to 73.1 on fresh weight basis (Table 5).

Table 5: Cassava proximate analyses in Tanzania and Mozambique

Cassava varieties	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)	Cyanogen (ppm)
Tanzanian varieties							
Kiroba	57.30	3.42	0.9	0.20	1.30	30.52	80.0
Mzuri.Kwao	59.60	3.19	1.1	0.18	1.02	29.60	90.0
Mumba	61.00	3.29	0.6	0.12	0.80	28.48	65.0
Kigoma	59.20	3.20	0.8	0.35	1.21	20.33	
Mozambican varieties							
Chinhembué	63.54	2.62	1.7	0.31	0.84	30.52	80.0
Kusse	64.51	2.82	1.5	0.30	1.3	29.59	120.0
Nhambatsana	65.50	2.78	1.7	0.23	0.89	28.48	80.0
Tchicela ni tchai	73.10	3.20	1.8	0.35	1.20	20.33	70.0

This variation was partly due to the fact that while in Tanzania some of the varieties were harvested during the rainy season, others were harvested during the dry season. Cassava varieties and climate differences could result in what was observed in the study. The ash content of the cassava varieties did not differ much. Similarly, the fat content did not show striking differences and was less than one in all varieties. The crude fibre was almost the same range in all varieties. The protein content was low in all varieties and in all countries. Table 6 shows the cowpea and wheat proximate compositions.

Table 6: Cowpea and wheat proximate analyses in Tanzania and Mozambique

Crop varieties	Moisture (%)	D. matter (%)	Ash (%)	Protein (%)	Fat (%)	C. fibre (%)	Carbohydrate (%)
Tanzanian crops							
Wheat	12.50	87.50	1.55	11.9	0.96	1.70	71.39
Cowpea	14.00	81.22	4.17	24.1	1.90	2.65	47.45
Mozambican crops							
Wheat	11.50	90.61	1.60	11.7	0.90	1.85	72.45
Cowpea	9.47	90.53	4.06	24.0	1.20	3.32	54.95

The data shows that the ash content of cowpea flour was higher than that of wheat flour thus exposing the benefits of cowpea inclusion as it increased the mineral content of the formulation. The crude protein was more than double, again reflecting the benefits of cowpea inclusion in the composite flour formulation. Fat content was higher in cowpea though not as conspicuous as the previous components and the disadvantage of cowpea was in connection with increased fibre content and decreased content of carbohydrate that could definitely lower the energy density of the formulations from carbohydrate point of view.

4.2 Characteristics of the composite bread and sensory attribute

The organoleptic characteristics of the cassava and cowpea composite breads altered the properties of the resulting breads (Plate 2-7).

4.2.1 Crust colour and structure

The crust colour of the conventional whole wheat bread was golden and cream white, bright and smooth. The 5% and 10% cassava composite bread had similar characteristics as the whole wheat bread. As the level of cassava flour in the blends was increased, the crust coulor of the breads became whitish. Furthermore, it was observed that in pan type bread it also needed more time than the control to acquire the golden colour during baking and the crust was also slightly hard due to the low amount of protein in cassava. The crust colour of all cassava composite breads was good, although it decreased slightly in appearance, the biggest snag being the roughness that reduced the acceptability by the consumer. For cowpea blends (Plates 3 and 6), as the level of cowpea increased in the formulation, the colour changed to strong brown and the crust became hard. The dark crust colour in cowpea composite bread was because of the greater chances for the Maillard reaction between reducing sugars and protein that occured as supported by Raidi and Klein (1983). It was further observed that cowpea pan bread type of 5 and 10% cowpea had crust colour that was more attractive than the whole wheat bread showing that cowpea could be used as colour improver.

The structure of the whole wheat bread was almost the same as that of 5 and 10% composite cassava breads. The crumb of whole wheat bread was soft and the air cells were evenly distributed as supported by Dhingra and Jood (2002). For 5 and 10% cassava composite breads, the air cells were big, variable in size and not evenly distributed. As the amount of cassava in the composite flour was increased, the roughness and slight hardness of the crumb structure was observed. For 15 and 20%

(a): 100% wheat bread **(b) 5% cassava composite bread**

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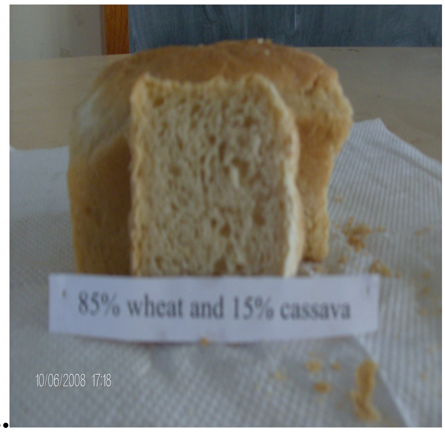


(c) 10% cassava composite bread **(d) 15% cassava composite bread**

(f) 20% cassava composite bread

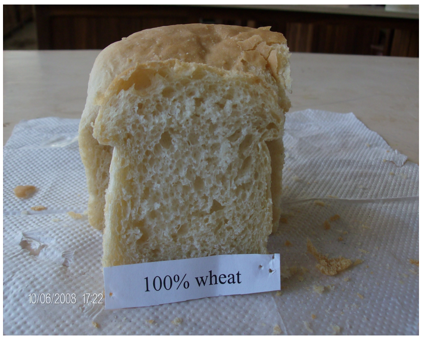
Plate 2: Cassava composite breads and whole wheat bread

(a) whole wheat bread **(b) 5% cowpea composite bread**

(c) 10% cowpea composite bread **(d) 15% cowpea composite bread**

(e) 20% cowpea composite bread **(f) 30% cowpea composite bread**

Plate 3: Cowpea composite breads

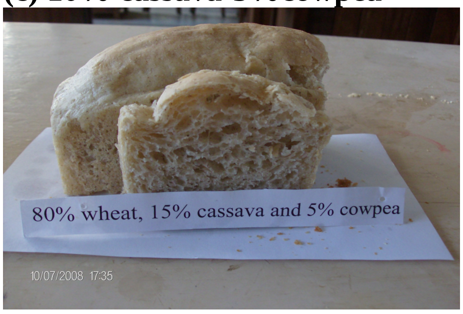


(a) **100% wheat bread**

(b) 5% cassava-5% cowpea composite bread

(c) 10% cassava-5%cowpea

(d) 5%cassava-10%cowpea



(e) 15% cassava-5%cowpea

(f)10% cassava-10%cowpea

(g) 5% cassava-15%cowpea

Plate 4: Combined cassava-cowpea composite breads

(a) 100% whole wheat pan bread **(b) 5% cassava composite pan bread**

(c) 10% cassava composite pan bread **(d) 15% cassava composite pan bread**

(e) 20% cassava composite pan bread

Plate 5: Cassava composite pan breads

(a) 100% wheat pan bread **(b) 5% cowpea pan composite bread**

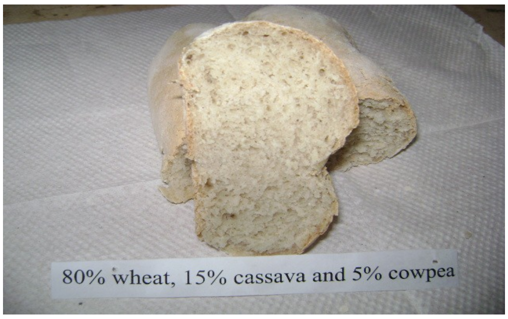
(c): 10%cowpea composite pan bread **(d) 15% cowpea composite pan bread**

(e) 20% cowpea composite pan bread **(f) 30% cowpea composite pan bread**

Plate 6: Cowpea composite pan breads

(a) 100% wheat pan bread (b) 5% cowpea-5% cassava composite pan bread

(c) 10% cassava-5% cowpea pan (d) 5% cassava-10% cowpea pan



(e) 5% cassava-15% cowpea pan (f) 15% cassava-5% cowpea pan

(g) 10% cassava-10%cowpea pan

Plate 7: Cassava-cowpea composite pan breads

cassava composite flour breads, the air cells were small, compacted and the structure was denser (Dhingra and Jood, 2002). The light, evenly structured bread made of wheat flour and the characteristic soft crumbs were due to the swelling properties of wheat-flour gluten in water. If pure starch from another cereal or tuber is used, the product is considerably more rigid and its shape is irregular because gases are insufficiently retained in the dough. As the dilution increased the air cells became smaller and structure compacted. This means that although bread can be produced from composite flours, the gluten content forms an important requirement in the structure and compactness of the bread as it influences air retention during baking of the bread. In the case of cowpea composite breads (Plate 3 and 6), as the amount of cowpea increased, the structure became hard, denser and colour changes were observed. The air cells were not evenly distributed. Regarding the crust, cowpea composite breads, revealed that as the amount of cowpea was increased, the air cells became bigger. It is important to note that although cowpeas improve the nutrient content of the blend, if not carefully done it will result in a poorly accepted bread from crust, colour and compactness point of view.

4.2.2 Appearance

The appearance of all composite breads decreased as the substitution of either cassava or cowpea flour increased. This is similar to previous observation by Dhingra and Jood (2002). The colour of cowpea /wheat pan bread at 5 and 10% substitution was the best suggesting the use of this proportion as a bread colour improver. Plates 5, 6 and 7 show the appearance of pan type bread.

4.2.3 Flavour

Whole wheat bread had a normal taste of bread, 5% composite bread, had no pronounced flavour, while 15, 20 and 30% cowpea composite bread had a pronounced flavour of cowpea. The bread flavour for cassava composite bread was weakly affected because cassava flavor is dull. The flavour of the composite bread was affected by the flavour of diluents at increased level of substitution, from 15, 20 to 30%, which is similar to results by Sharma (2000). Some panelists complained about a certain kind of smell coming from cowpea bread, whereas the same was not found in cassava composite bread. From the results, it is evident that use of cowpea introduces a beany flavour in the product. Therefore, besides other things, the level of substitution of wheat with cowpea has a pronounced effect on the bread prepared from the resulting composite flour.

4.2.4 Grain size

The grain size in whole wheat bread was the smallest while for composite flour as the non wheat increased the grain sizes became bigger and bigger.

4.2.5 Cell structure

The cell structure of whole wheat bread was uniform, evenly grained and with a silky crumb. The 5% cassava composite bread followed and the last was 30% cowpea composite bread, where the air cells were smallest in size and distribution. In cassava composite bread, as the amount of diluents was increased the cell structure became denser and compacted. In 5 and 10% composite bread, the structure was normal but with some big cells. As the cassava in the composite flour was increased to 15 and 20% the structure became dense and evenly distributed, but the air cells got reduced in size.

4.2.6 Crumb colour

The colour of whole wheat flour bread, was whitish (bright). The darkness in colour increased from 5% cowpea composite bread to 30% composite bread, with strong brown colour. Whole wheat bread was the softest.

4.2.7 Chewness

The 100% wheat bread was more elastic than 5, 10 and 15% composite breads, which were elastic. However, 20 and 30% formulations had a big decrease in elasticity. This was expected because elasticity was caused by gluten level that was reduced as more of the wheat-bread got replaced by other non-wheat flours.

4.2.8 Taste

Whole bread had the best overall quality followed by 5% composite bread. Increase in the proportion of non-wheat flours in the formulations led to decrease in the taste acceptance of the breads.

4.2.9 Overall acceptability

On the basis of the organoleptic attributes, the overall acceptability of the composite flour breads made from cassava and cowpea up to 20 and 30% cowpea substitution, was significantly reduced as compared to that of whole wheat bread. At high level of substitution, these attributes were not acceptable to people who were accustomed to conventional bread as some panelists said that there was a certain kind of smell coming from cowpea composite bread. While formulation has the objective of exploiting underutilized staples, acceptability of such formulations will depend on what cereal or legume is used in the formulation and the level of inclusion.

4.3 Correct proportions of wheat, cassava and cowpea flours in bread

All proportions seems to be right and good when compared with cassava and whole wheat bread, because both are poor sources of quality protein due to the deficiency of some essential amino acids such as lysine and threonine (Hooda and Jood, 2005). A good bread in terms of good nutrition is the cowpea composite bread and the mixture cassava-cowpea composite bread. The good proportions in terms of nutrients are 10, 15, 20 and 30% cowpea. Also, composite bread of combined 5% cassava and 10% cowpea gave a relative high quality protein bread. Cowpea is a protein rich grain (25%) and rich in lysine. Therefore, it was used for fortification of wheat bread, improving not only the protein content but quality and also fibre, ash, fat, and mineral contents. In any case, cassava inclusion is beneficial from food security point of view and inclusion of cowpea in the formulation has nutritional benefits to cassava or wheat consumers.

4.4 Acceptance by consumers

Some panelists, were not familiar with bread, to the extent that they failed to identify a pure wheat bread in both countries. In Tanzania, this may be due to the fact that, during breakfast time, bread is not the main dietary component, especially in rural areas. In Mozambique, this may be due to the fact that, peasants have got shortage of money and is not usual to get bread every day.

4.4.1 Taste of the samples

In Tanzania, the mean score for taste ranged from 3.03 to 4.87, the high value being for 20% cowpea and the lowest value for 20% cassava (Table 7). It showed that in Tanzania, 20% cowpea composite bread was more preferred than whole wheat bread. Some panelists showed a total dislike of some of the composite breads. No panelist showed a total dislike of the 10 and 30% cowpea composite bread, 15% cassava composite bread, the combined 10% cassava-5% cowpea, 5% cassava-15% cowpea, 15% cassava-5% cowpea and 10% cassava-10% cowpea composite breads. The ratings, for the taste of the composite bread produced in Mozambique were comparable to those of 100% wheat bread and ranged from 4.80 to 3.53 (Table 8). No panelist showed a total dislike for the whole wheat bread, 5 and 15% cassava composite bread, 15% cowpea composite bread and 30% cowpea composite bread. Some panelists, however, showed a total dislike for the tastes of some of the samples, implying that the taste of the samples was affected by the level of substitution of the wheat. The mean scores for 5, 10 and 20% composite breads were higher than that of the control (whole wheat bread), showing that cassava composite bread tasted better than the whole wheat bread. For cowpeas composite bread, the mean scores were high for 15% cowpea than that of whole wheat flour. In the case of for 5 and 10% cowpea composite bread the mean scores did not differ significantly ($p>0.05$) from the whole wheat bread.

Table 7: Mean hedonic scores for sensory attributes of Tanzanian bread samples

Form.	Composition Wht:cas:cow*	Taste	Colour	Aroma	Loaf volume	Overall Accept.	Buying pref.
1	100:0:0	3.87[a]	3.80[a]	3.47[b]	3.80[a]	3.87[a]	4.16[a]
2	95:5:0	3.90[a]	3.60[b]	3.70[b]	3.50[b]	3.60[b]	3.73[b]
3	95:0:5	3.13[b]	4.00[a]	3.17[c]	3.03[c]	3.36[b]	3.37[b]
4	90:0:10	3.80[a]	3.40[b]	3.60[b]	3.90[a]	3.63[b]	3.73[b]
5	90:10:0	3.63[b]	4.00[a]	4.13[a]	3.97[a]	3.75[b]	3.63[b]
6	90:5:5	3.83[a]	3.97[a]	3.67[b]	4.40[a]	3.97[a]	3.83[a]
7	95:0:15	3.90[a]	3.63[b]	3.43[b]	3.30[b]	3.70[b]	3.47[b]
8	95:15:0	3.50[b]	4.00[a]	3.33[b]	3.87[a]	3.60[b]	3.10[c]
9	85:5:10	4.07[a]	3.73[a]	3.42[b]	3.53[b]	3.73[b]	3.27c
10	85:10:5	3.43[b]	3.97[a]	3.77[b]	3.76[b]	3.90[a]	3.60[b]
11	80:0:20	4.87[a]	3.43[b]	3.60[b]	3.23[c]	3.70[b]	3.17[c]
12	80:20:0	3.03[c]	3.40[b]	3.47[b]	3.43[b]	3.23[c]	3.23[c]
13	80:5:15	3.67[b]	4.33[a]	4.03[a]	3.40[b]	3.90[a]	3.67[b]
14	80.15:5	4.43[a]	4.27[a]	4.27[a]	4.13[a]	4.20[a]	3.90[a]
15	80:10:10	4.10[a]	4.03[a]	3.97[b]	4.03[a]	3.90[a]	3.83[a]
16	70:0:30	3.20c	3.23[a]	2.80[c]	3.20c	2.90[c]	2.47[c]

*Wht:cas:cow-wheat:cassava:cowpea

Mean scores in same columns with different superscript letters are significantly different ($p < 0.05$)

Table 8: Mean hedonic scores for sensory attributes of Mozambican bread samples

Form.	Composition Wht:cas:cow*	Taste	Color	Smell	Loaf volume	Overall Accept.	Buying preferece
1	100:0:0	4.30[a]	4.17[b]	4.17[b]	4.40[a]	4.53[a]	4.25[a]
2	95:5:0	4.50[a]	4.37[b]	4.43[b]	4.30[a]	4.57[a]	4.19[a]
3	95:0:5	4.17[a]	4.28[a]	4.37[a]	4.17[a]	4.07[a]	4.45[a]
4	90:0:10	4.00[a]	4.37[a]	3.37[b]	3.90[b]	4.50[a]	4.69[a]
5	90:10:0	4.37[a]	4.50[a]	4.27[a]	4.27[a]	4.20[a]	4.50[a]
6	90:5:5	4.80[a]	4.50[a]	4.33[a]	4.33[a]	4.13[a]	4.21[a]
7	95:0:15	4.60[a]	4.37[a]	4.17[a]	4.17[a]	3.90[b]	3.14[c]
8	95:15:0	4.00[a]	3.47[b]	4.24[a]	3.73[b]	4.23[a]	4.06[a]
9	85:5:10	3.87[a]	3.90[a]	3.57[b]	3.57[b]	3.63[b]	3.56[b]
10	85:10:5	3.93[a]	4.07[a]	3.97[a]	3.97[a]	3.77[b]	3.00[c]
11	80:0:20	3.53[b]	3.77[a]	3.37[b]	3.37[b]	3.27[c]	3.31[c]
12	80:20:0	4.47[a]	3.57[b]	4.23[a]	3.83[a]	4.27[a]	4.19[a]
13	80:5:15	4.47[a]	4.50[a]	3.83[a]	4.23[a]	3.23[c]	3.23[c]
14	80.15:5	3.87[a]	4.10[a]	4.13[a]	4.13[b]	3.80[b]	4.35[a]
15	80:10:10	4.53[a]	4.30[a]	3.83[a]	3.83[a]	4.23[a]	4.40[a]
16	70:0:30	4.33[a]	3.70[b]	3.87[a]	3.87[a]	3.77[b]	3.12[c]

*Wht:cas:cow-wheat:cassava:cowpea

Mean scores in columns with same letters are not significantly different ($p < 0.05$)

This suggests that the quality of bread that can be produced from wheat-cassava-cowpea flour mixtures depend on the level of substitution. Lower level of inclusion of cassava or cowpea or both result in acceptable taste in the bread, but when levels of inclusion are raised further it ends up worsening the taste of the resulting bread. With cowpea, however, the nutrients are improved but with cassava they are diluted in the final product. There is a need to always strike a balance between the sensory and nutritional gains when attempts are made to produce composite flour bread.

4.4.2 Aroma of the samples

In Tanzania, the mean scores for the bread aroma ranged from 2.80 to 4.27 (Table 7). The mean score for aroma was low for the 30% cowpea bread and high for the combination 15% cassava-5% cowpea. It was observed that the best aroma was found in composite bread instead of whole wheat bread. No panelist showed a total dislike of the aroma for whole wheat bread, 10% and 20% cowpea composite bread, 10, 20% cassava composite bread, the combination 5% cassava-5% cowpea composite bread, 5% cassava-15% cowpea, 15% cassava-5% cowpea and 10% cassava-10% cowpea. Only the 30% cowpea was disliked by the panelists.

The aroma scores in Mozambique ranged from 3.37 for 15% cowpea composite bread to 4.43 for 5% cassava composite bread (Table 8). No panelist showed a total dislike for 5% cassava composite bread up to 20%cassava; 5% cowpea up to 20% cowpea composite bread; the combination 5% cassava-5% cowpea composite bread; 5% cassava-10% cowpea; 5% cassava and 15% cowpea composite bread. For 5 and 10% cassava composite bread the scores were higher than whole wheat bread, showing that certain level of substitution improves the bread aroma. The 5% cowpea composite bread scored higher than whole wheat bread. No panelists showed a total dislike for some bread aroma. Substitution of wheat with cowpea in bread production has an influence on the aroma of the product.

4.4.3 Composite bread colour

The mean scores of colour for Tanzanian composite bread (Table 7) ranged from 3.23 to 4.27. The highest value was for 5% cowpea composite bread, and the lowest value was for 30% cowpea composite bread. No panelist showed a total dislike for 5, 10, 15 and 20% cassava composite bread, 5% cowpea composite bread, the combination 10% cassava-5% cowpea; 5% cassava-15% cowpea; 15% cassava-5% cowpea; 10% cassava-10% cowpea and 30% cowpea composite bread. The colour of bread in Mozambique ranged from 3.47 for 15% cassava to 4.50 for 5 % cassava or 10% cassava or 15% cowpea composite bread. The 5 and 10% cowpea composite breads showed attractive colours. For example, since whole wheat bread colour is not very attractive, such combinations may be used for improvements. The worst colour was showed by 30% cowpea composite bread mainly due to the excessive Maillard reaction. Overrall, no panelist showed total dislike for 5, 10% cassava composite bread and 5, 10, 15% cowpea composite breads, the combination 5% cassava-5% cowpea; 15% cassava-5% cowpea, and 10% cassava-10% cowpea.

4.4.4 Loaf volume

In Tanzania, the mean bread loaf volume scored from 3.03 to 4.40 (Table 7). The smallest value was for 30% cowpea and the highest value for the combination 5% cassava-5% cowpea. No panelist showed total dislike for whole wheat flour, 5, 10, 15 and 20% cassava composite bread, the combination 10% cassava-5% cowpea; 15% cassava-5% cowpea and 10% cassava-10% cowpea. These results showed that at low levels of inclusion of these non-wheat flours, bread of acceptable volume could be produced. The loaf size is one of the characteristic measures of bread.

The mean value of loaf volume from Mozambican panelists ranged from 3.37 to 4.40 (Table 8). The smallest mean was for 20% cowpea bread and the highest value for 100% wheat flour. In Mozambique, no panelist showed a total dislike for the whole wheat bread, 5 and 10% cassava composite bread, and the combination 5% cassava-5% cowpea. As well as for 5, 10 and 15% cowpea composite bread. In addition, formulations with the combination 5% cassava-15% cowpea; 15% cassava-5% cowpea; 10% cassava-10% cowpea and 30% cowpea composite bread were also accepted. Neither cassava nor cowpea at the levels used could maintain the loaf volume. This showed that once included in the formulation, since they do not contain gluten it will definitely lower the loaf volume. However, there are tolerable levels of inclusion that need to be observed in order to produce acceptable bread.

4.4.5 Buying preference

In Tanzania, the mean scores for preference in buying ranged from 2.47 to 4.16 (Table 7). The smallest mean was for 30% cowpea composite bread and the highest mean value for whole wheat bread. It was observed that even though people are choosing composite bread in other attributes when it comes to buying, they prefer to buy the whole wheat bread instead of composite bread. However, no panelist showed total dislike in buying whole wheat bread, 5% and 10% cassava bread, 5 10, 15 and 30% cowpea bread.

In Mozambique, preference in buying scored means that ranged from 3.00 to 4.69 with the highest being recorded for 10% cowpea composite bread, and the lowest for 10% cassava-5% cowpea composite breads. However, the acceptability of the samples was comparable to that of the whole wheat bread. The buying preference of the cassava composite bread did not differ significantly from that of whole wheat bread. The buying preference of the cowpea composite bread for 5 and 10% level of substitution was higher than of the whole wheat bread but, as the substitution of non-wheat flours was increased, the colour was affected by the high level of browning reactions sometimes leading to burnt colour and this tended to affect negatively the preference to buy. No panelist showed total dislike in buying whole wheat bread, 5, 10 and 15% cassava composite bread, 5 and 10% composite cowpea bread and the combination 5% cassava-5% cowpea composite bread. The rest were generally disliked.

4.4.6 Overall acceptability

The mean score for the Tanzanian bread formulations ranged from 2.90 to 3.97 (Table 7). The lowest value was for 30% cowpea and the highest value for the combination 5% cassava-5% cowpea. No panelist showed a total dislike for 10 and 15% cassava composite bread; 10 and 20% cowpea composite bread, the combination 5% cassava-10% cowpea, 10% cassava -5% cowpea, 5% cassava-15% cowpea, 15% cassava-5% cowpea and 10% cassava -10% cowpea composite bread.

The mean overall acceptability scores of Mozambique samples, ranged from 3.23 to 4.57, the latter being the highest mean scores for 5% cassava composite bread and the lowest value for the combination 5% cassava-10% cowpea composite bread. In Mozambique, no panelist showed total dislike for whole wheat bread, 5% cassava, 5% cowpea and 10% cowpea, the combination 10% cassava-5% cowpea and 10% cassava-10% cowpea. It was observed that composite bread from both countries was quite highly accepted by consumers. The results obtained in this study have highlighted the benefits likely to be obtained from using non-wheat flours in making conventional as well as pan bread. These lie in increasing utilization of cassava in baked products and also exploiting the nutritional quality of cowpeas in the baking. In addition, where wheat is unaffordable, part of the wheat flour could be substituted with cassava flour and still produce an acceptable product. Such a move could have a positive impact on household food security.

4.5 Physical and chemical properties of the composite bread

4.5.1 Bread proximate analysis

Chemical composition of composite flour bread involving *Kigoma* cassava variety is detailed in Table 9. The moisture content of the breads ranged between 27.02 and 40.82%, most of them lying close to 28 and 34% moisture content. The protein content was in the range between 8.3 and 15.7%. It was evident that inclusion of cassava alone diluted the protein in the formulation, highest dilution coming from bread with highest cassava in the formulation. Cowpea inclusion on the other hand elevated the protein content, being highest in the 70:30 combinations that produced highest values of protein content (Table 9).

Table 9: Kigoma composite bread composition

Types	Form.	Composition Wht:cas:cow*	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
	1	100:0:0	29.00	10.7	1.23	1.80	1.60	55.67
	1	100:0:0	28.02	10.5	1.20	1.75	1.60	56.93
Unsoaked	2	95:5:0	28.02	10.04	1.57	1.75	1.48	55.14
Soaked	2	95:5:0	28.00	10.0	1.30	1.67	1.61	57.42
	3	95:0:5:	30.82	11.3	1.20	1.84	1.73	51.86
	3	95:0:5	29.92	10.7	1.34	1.78	1.93	54.33
	4	90:0:10	32.92	12.2	1.40	1.89	1.92	48.59
	4	90:0:10	30.02	11.4	1.48	1.80	2.15	53.15
Unsoaked	5	90:10:0	29.89	10.4	1.28	1.60	1.64	53.89
Soaked	5	90:10:0	27.02	9.1	1.4	1.60	1.53	59.35
Unsoaked	6	90:5:5	32.08	10.8	1.30	1.90	1.90	52.02
Soaked	6	90:5:5	32.91	10.3	1.44	1.75	1.84	51.76
	7	85.0:15	32.02	12.7	2.08	1.96	1.40	47.60
	7	85:0:15	31.36	12.1	1.62	1.85	2.38	50.69
Unsoaked	8	85:15:0	27.32	9.8	1.69	1.40	1.60	56.19
Soaked	8	85:15:0	28.20	8.7	1.5	1.54	1.45	58.61
Unsoaked	9	85:5:10	33.67	12.3	1.90	1.83	1.93	46.37
Soaked	9	85:5:10	32.82	11.2	1.58	1.79	2.06	50.55
Unsoaked	10	85:10:5	33.91	11.0	1.99	1.90	1.5	47.70
Soaked	10	85:10:5	32.74	9.8	1.54	1.78	1.75	52.39
	11	80:0:20	34.29	14.4	2.59	1.97	2.29	42.46
	11	80:0:20	33.73	12.8	1.76	1.94	2.62	47.15
Unsoaked	12	80:20:0	28.23	9.0	2.39	1.30	1.99	56.09
Soaked	12	80:20:0	28.29	8.3	1.80	1.38	1.35	58.87
Unsoaked	13	80:5:15	30.34	12.2	2.20	1.85	2.02	49.39

Soaked	13	80:5:15	32.29	11.7	1.72	1.95	2.29	50.05
Unsoaked	14	80:15:5	33.45	10.5	2.00	1.80	1.8	48.43
Soaked	14	80:15:5	30.99	9.4	1.64	1.87	1.66	54.44
Unsoaked	15	80:10:10	34.03	12.2	1.73	1.85	2.2	45.99
Soaked	15	80:10:10	33.24	10.5	1.68	1.89	1.98	50.71
	16	70:0:30	40.82	15.7	2.29	1.98	2.50	36.71
	16	70:0:30	39.89	14.2	2.04	2.20	3.05	38.62

*Wht:cas:cow-wheat:cassava:cowpea

Table 10: Kiroba composite bread composition

Type	Form	Composition Wht.cas.cow*	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
	1	100:0:0	28.32	11.0	1.34	1.50	1.70	56.14
	1	100:0:0	27.23	11.0	1.50	1.70	1.75	56.82
Unsoaked	2	95:5:0	27.32	10.5	1.57	1.45	1.55	57.58
Soaked	2	95:5:0	26.99	10.5	1.57	1.67	1.60	57.67
	3	95:0:5:	28.50	11.7	1.61	1.85	1.75	54.59
	3	95:0:5	29.12	11.7	1.61	1.75	1..80	54.02
	4	90:0:10	30.34	12.4	1.72	1.93	1.79	51.82
	4	90:0:10	30.00	12.4	1.72	1.79	1.84	52.25
Unsoaked	5	90:10:0	27.59	10.1	1.56	1.34	1.45	57.93
Soaked	5	90:10:0	27.23	10.2	1.60	1.60	1.58	57.70
Unsoaked	6	90:5:5	31.03	11.2	1.64	1.92	1.59	54.11
Soaked	6	90:5:5	30.88	11.2	1.64	1.70	1.64	52.94
	7	85.0:15	33.06	13.1	1.83	1.99	1.82	48.26
	7	85:0:15	31.78	13.1	1.83	1.80	1.87	49.62
Unsoaked	8	85:15:0	28.01	9.0	1.28	1.40	1.41	58.90
Soaked	8	85:15:0	26.24	9.7	1.59	1.62	1.46	59.39
Unsoaked	9	85:5:10	34.21	11.9	1.75	1.26	1.76	49.05
Soaked	9	85:5:10	32.23	11.9	1.75	1.79	1.81	50.52
Unsoaked	10	85:10:5	33.38	10.8	1.67	1.13	1.47	51.52
Soaked	10	85:10:5	31.05	10.8	1.67	1.72	1.52	53.24
	11	80:0:20	32.5	13.8	1.94	1.48	1.88	48.38
	11	80:0:20	32.39	13.8	1.94	1.96	1. 93	47.98
Unsoaked	12	80:20:0	28.23	9.2	1.62	1.20	1.40	58.29
Soaked	12	80:20:0	27.79	9.55	1.75	1.56	1.45	57.90
Unsoaked	13	80:5:15	32.34	12.67	1.86	1.60	1.80	49.73

Soaked	13	80:5:15	32.32	12.7	1.86	1.40	1.80	48.92
Unsoaked	14	80:15:5	32.46	10.40	1.70	1.52	1.44	52.48
Soaked	14	80:15:5	31.27	10.4	1.7	1.65	1.49	53.49
Unsoaked	15	80:10:10	33.12	11.53	1.78	1.46	1.60	50.51
Soaked	15	80:10:10	34.27	11.60	1.79	1.60	1.65	49.09
	16	70:0:30	39.50	15.21	2.16	2.10	2.28	38.75
	16	70:0:30	38.27	15.2	2.16	2.10	2.32	39.95

*Wht:cas:cow-wheat:cassava:cowpea

Table 11: Mzuri.Kwao composite bread composition

Type	Form.	Composition Wht:cas:cow*	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
	1	100:0:0	28.78	11.0	1.50	1.60	1.45	55.67
		100:0:0	28.02	10.7	1.25	1.60	1.80	57.43
Unsoaked	2	95:5:0	27.45	10.5	1.53	1.52	1.06	55.91
Soaked	2	95:5:0	27.82	10.1	1.32	1.56	1.68	57.52
	3	95:0:5:	29.32	11.7	1.72	1.65	2.00	51.61
	3	95:0:5	29.00	10.9	1.52	1.74	1.84	55.00
	4	90:0:10	30.00	12.4	1.70	1.75	1.90	50.25
	4	90:0:10	32.89	11.4	1.55	1.79	1.89	50.48
Unsoaked	5	90:10:0	28.05	10.1	1.60	1.31	1.49	55.49
Soaked	5	90:10:0	27.00	9.58	1.43	1.50	1.45	57.82
Unsoaked	6	90:5:5	31.78	11.2	1.64	1.60	1.80	49.95
Soaked	6	90:5:5	30.08	10.2	1.60	1.72	1.59	54.05
	7	85.0:15	32.60	13.1	1.83	1.80	2.54	46.13
	7	85:0:15	33.42	12.1	1.82	1.80	1.93	48.93
Unsoaked	8	85:15:0	27.90	9.6	1.67	1.52	1.67	55.65
Soaked	8	85:15:0	27.98	9.0	1.70	1.43	1.80	58.58
Unsoaked	9	85:5:10	34.28	11.9	1.83	1.82	2.19	45.95
Soaked	9	85:5:10	33.52	10.9	1.69	1.75	1.76	49.31
Unsoaked	10	85:10:5	32.62	10.8	1.66	2.00	2.58	49.38
Soaked	10	85:10:5	35.00	9.7	1.63	1.67	1.47	49.71
	11	80:0:20	34.00	13.8	1.94	1.90	2.60	43.76
	11	80:0:20	34.00	12.8	1.87	1.92	1.98	47.43
Unsoaked	12	80:20:0	27.39	9.1	1.72	1.40	1.28	57.11
Soaked	12	80:20:0	28.27	8.1	1.63	1.38	1.40	58.22
Unsoaked	13	80:5:15	30.56	12.6	2.00	1.89	2.47	42.45

Soaked	13	80:5:15	32.52	11.6	1.87	1.72	1.84	50.41
Unsoaked	14	80:15:5	32.89	10.3	1.72	1.78	1.59	49.72
Soaked	14	80:15:5	34.02	9.32	1.72	1.67	1.44	50.94
Unsoaked	15	80:10:10	34.27	11.5	2.01	1.85	2.27	46.10
Soaked	15	80:10:10	33.63	10.48	1.76	1.60	1.60	50.32
	16	70:0:30	38.42	15.2	2.26	2.62	2.79	36.71
	16	70:0:30	39.03	14.2	2.00	2.31	2.50	40.15

*Wht:cas:cow-wheat:cassava:cowpea

Table 12: Mumba bread composite bread composition

Type	Form.	Composition Wht:cas:cow*	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
	1	100:0:0	26.79	11.0	1.32	1.60	1.50	56.99
	1	100:0:0	26.32	10.8	1.23	1.70	1.60	58.98
Unsoaked	2	95:5:0	25.36	10.0	1.42	1.56	1.45	59.21
Soaked	2	95:5:0	26.09	10.4	1.28	1.66	1.59	58.98
	3	95:0:5:	26.00	11.3	1.10	1.68	1.78	57.14
	3	95:0:5	28.45	11.2	1.30	1.72	1.70	55.63
	4	90:0:10	29.89	12.0	1.47	1.70	1.90	51.56
	4	90:0:10	29.03	11.5	1.23	1.79	2.13	52.32
Unsoaked	5	90:10:0	26.67	9.9	1.22	1.44	1.40	59.37
Soaked	5	90:10:0	27.02	10.0	1.50	1.45	1.56	58.52
Unsoaked	6	90:5:5	31.23	11.2	1.38	1.40	1.50	51.72
Soaked	6	90:5:5	30.49	10.7	1.34	1.82	1.92	53.73
	7	85.0:15	32.67	12.7	1.50	1.60	2.10	48.43
	7	85:0:15	32.89	12.3	1.67	1.78	2.27	49.19
Unsoaked	8	85:15:0	25.50	8.6	2.32	1.35	1.40	59.81
Soaked	8	85:15:0	27.35	9.00	1.40	1.40	1.20	59.65
Unsoaked	9	85:5:10	32.24	11.5	1.58	1.72	1.98	49.98
Soaked	9	85:5:10	32.01	11.5	1.40	1.56	2.15	51.38
Unsoaked	10	85:10:5	33.19	11.1	1.87	1.84	1.61	49.39
	10	85:10:5	34.43	10.3	1.90	1.46	1.69	50.22
	11	80:0:20	32.99	12.9	1.54	1.90	2.76	46.91
	11	80:0:20	35.38	13.0	1.15	1.98	2.0	46.49
Unsoaked	12	80:20:0	26.48	9.2	1.23	1.22	1.40	60.47
Soaked	12	80:20:0	27.03	9.5	1.60	1.32	1.4	59.15
Unsoaked	13	80:5:15	32.52	11.8	1.50	1.67	2.12	49.39
Soaked	13	80:5:15	32.67	12.0	1.60	1.60	2.2	48.93

Unsoaked	14	80:15:5	33.04	10.5	1.55	1.56	1.75	51.82
Soaked	14	80:15:5	33.02	10.8	1.60	1.36	1.80	54.42
Unsoaked	15	80:10:10	33.06	11.3	1.98	1.60	2.2	48.86
Soaked	15	80:10:10	34.2	11.0	1.48	1.43	1.8	50.09
	16	70:0:30	38.95	14.0	2.76	2.39	2.60	37.62
	16	70:0:30	39.12	13.5	1.95	2.35	2.30	40.78

*Wht:cas:cow-wheat:cassava:cowpea

Table 13: Nhambatsana composite bread composition

Form.	Compositions Wht:cas:cow*	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
1	100:0:0	31.72	1.13	10.5	0.60	1.60	54.44
2	95:5:0	30.50	1.24	10.1	0.47	1.50	56.19
3	95:0:5	30.78	1.29	11.2	0.62	1.67	54.44
4	90:0:10	32.30	1.40	11.9	0.73	1.69	51.98
5	90:10:0	29.50	1.32	9.5	0.48	1.40	57.8
6	90:5:5	32.58	1.37	10.7	0.60	1.65	53.10
7	95:0:15	34.03	1.56	12.6	0.85	1.75	49.21
8	95:15:0	31.03	1.43	9.1	0.47	1.30	56.67
9	85:5:10	33.00	1.52	11.4	0.72	1.90	51.46
10	85:10:5	32.98	1.43	10.2	0.59	1.60	53.20
11	80:0:20	34.56	1.69	13.3	0.96	2.00	47.49
12	80:20:0	30.79	1.50	8.6	0.46	1.52	57.13
13	80:5:15	34.08	1.70	12.1	0.84	2.12	49.16
14	80:15:5	35.00	1.57	9.8	0.58	1.52	51.53
15	80:10:10	34.23	1.63	10.9	0.70	1.82	50.72
16	70:0:30	36.04	2.01	14.7	1.19	2.45	43.61

*Wht:cas:cow-wheat:cassava:cowpea

Table 14: Kusse composite bread composition

Form.	Composition Wht:cas:cow*	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
1	100:0:0	30.79	10.8	1.10	0.70	1.80	54.81
2	95:5:0	30.80	10.30	1.26	0.57	1.70	55.37
3	95:0:5	32.05	11.50	1.35	0.52	2.10	52.48
4	90:0:10	32.78	12.2	1.46	0.63	2.30	50.63
5	90:10:0	29.26	9.8	1.32	0.58	1.50	57.24
6	90:5:5	33.67	11.0	1.38	0.50	1.80	51.65
7	95:0:15	32.71	12.9	1.57	0.75	2.00	50.07
8	95:15:0	30.30	9.4	1.39	0.37	1.48	57.06
9	85:5:10	34.40	11.7	1.52	0.62	1.87	49.89
10	85:10:5	34.52	10.5	1.43	0.69	1.67	51.19
11	80:0:20	33.18	13.5	1.67	0.86	2.20	48.59
12	80:20:0	30.74	8.9	1.45	0.56	1.46	56.89
13	80:5:15	34.73	12.8	1.63	0.74	1.98	48.12
14	80:15:5	35.28	12.3	1.52	0.68	1.65	48.57
15	80:10:10	34.78	11.2	1.57	0.60	1.70	50.15
16	70:0:30	36.00	15.0	2.19	1.25	2.40	43.16

*Wht:cas:cow-wheat:cassava:cowpea

Table 15: Chinhembué composite bread composition

Form.	Composition Wht:cas:cow*	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	C. fibre (%)	Carbohyd. (%)
1	100:0:0	30.45	11.0	1.10	0.65	1.70	55.10
2	95:5:0	30.30	10.6	1.27	0.56	1.61	55.66
3	95:0:5	32.53	11.8	1.33	0.70	1.74.	51.90
4	90:0:10	33.78	12.4	1.47	0.75	1.79	49.81
5	90:10:0	30.24	11.1	1.34	0.52	1.58	55.22
6	90:5:5	34.15	11.2	1.40	0.66	1.72	50.87
7	95:0:15	34.47	13.1	1.60	0.79	1.84	48.20
8	95:15:0	30.50	10.5	1.41	0.48	1.43	55.68
9	85:5:10	34.50	11.9	1.54	0.74	1.79	49.53
10	85:10:5	33.46	10.8	1.47	0.54	1.50	52.23
11	80:0:20	35.42	13.8	1.74	0.84	1.94	46.26
12	80:20:0	30.00	9.1	1.48	0.40	1.30	57.72
13	80:5:15	32.34	12.6	1.67	0.74	1.72	50.93
14	80:15:5	32.60	10.2	1.55	0.43	1.50	53.72
15	80:10:10	35.92	11.4	1.61	0.60	1.52	48.95
16	70:0:30	36.50	15.2	2.01	1.10	2.13	43.06

*Wht:cas:cow-wheat:cassava:cowpea

Table 16: Tchicela ni Tchai composite bread composition

Form.	Composition Wht:cas:cow*	Moisture (%)	Protein (%)	Ash (%)	C. fibre (%)	Fat (%)	Carbohyd. (%)
1	100:0:0	32.02	10.5	1.10	1.75	0.75	53.88
2	95:5:0	32.00	10.0	1.30	1.67	0.71	54.32
3	95:0:5	33.45	11.2	1.33	1.84	0.73	51.45
4	90:0:10	35.60	11.9	1.47	1.89	0.72	48.42
5	90:10:0	31.03	9.5	1.40	1.50	0.67	55.90
6	90:5:5	34.78	10.7	1.43	1.60	0.70	50.79
7	95:0:15	36.02	12.6	1.60	2.20	0.71	46.87
8	95:15:0	32.04	9.1	1.50	1.47	0.64	55.89
9	85:5:10	34.79	11.4	1.57	1.85	0.78	49.61
10	85:10:5	34.05	10.2	1.53	1.45	0.76	52.01
11	80:0:20	35.37	13.3	1.74	2.24	0.90	46.45
12	80:20:0	32.45	8.6	1.60	1.40	0.56	55.39
13	80:5:15	33.80	12.1	1.70	1.98.	0.77	49.65
14	80:15:5	34.78	9.8	1.63	1.80	0.72	51.27
15	80:10:10	34.99	10.9	1.67	1.75	0.65	50.04
16	70:0:30	36.31	14.7	2.01	2.60	0.99	43.39

*Wht:cas:cow-wheat:cassava:cowpea

Ash content (Table 9) seems to increase when the proportion of cowpea was increased in the formulation. It shows that as expected, cowpea supplies more minerals than cassava as most of the dry matter in cassava is carbohydrate.

The fat content in cassava as expected was generally low (less than 2%) and seemed not to be influenced by soaking (Table 9). The fibre content did not show much variation caused by formulation, but again formulation with highest cowpea inclusion had consistently higher fibre than the rest. Formulations, with highest cassava had relatively lower values than that with highest cowpea content (Table 9).

Carbohydrate content was quite variable and was highest in cassava-based than in cowpea-based formulation (Table 9). This ranged from 36.71 to 59.35%. It can be concluded that inclusion of cassava increases carbohydrate content depending on the proportion used and that replacement of wheat with cowpea lowers the content of carbohydrate in the formulated bread. Composite flour during bread making should look at the nutrient and energy content, besides the sensory attribute and loaf volume of the bread. Soaking of cassava seems not to influence much the composition of the bread.

The results of chemical composition for the *Kiroba* composite bread are shown in Table 10. Just las was the case for Kigoma variety, moisture content of the bread did not vary much (26.24-39.59%). Samples with high cowpea content had generally higher moisture content, due to high power of the high content of protein to bind water, a property that was missing when high content cassava was used in the blending.

The crude protein of the soaked and unsoaked cassava used in the composite bread was so close to one another when samples were compared (Table 10). However, where more cassava replaced the wheat there was a corresponding reduction in the protein content. This was why formulations that were cassava–based had generally lower protein than the pure wheat or the cowpea-based formulations. Furthermore, formulations with cowpea had higher protein and that with highest cowpea inclusion had highest protein content (around 15.2%) compared to highest cassava inclusion that had lowest protein content, 9.26-9.55% (Table10).

The ash content showed a trend that was similar to the one observed for the Kigoma variety, ranging from 1.28-2.16%, again being highest in samples with highest cowpea inclusion (Table 10).

Crude fibre content did not show much variation but was highest in cowpea-based formulation with highest cowpea inclusion (Table 10). The range of the fibre content was 1.40-2.32%. Cowpea was therefore responsible for raising fibre content in the formulations, while inclusion of cassava made the composite bread less fibrous than the pure wheat bread. Carbohydrate content also showed close relation between related samples, but ranged between 38.75 and 59.39%, being highest in cassava-based and lowest in cowpea-based samples. The explanation given for *Kigoma* samples also holds for this *Kiroba* variety.

For *Mzuri.Kwao* variety (Table 11), the moisture content of the bread was comparable to that explained for *Kigoma* and *Kiroba*-based formulations. Crude protein, ash, fat and crude fibre as well as carbohydrate behaved in a similar manner explained for *Kiroba* and *Kigoma* varieties, particularly in relation to the trend. Soaking seemed not to influence much of the chemical composition of the formulations.

The fourth Tanzanian cassava variety studied was *Mumba*, whose, composite bread composition is shown in Table 12. There was no striking difference from the previous three varieties in terms of trend in chemical composition of the cassava-based and cowpea-based formulations. Protein, ash, fibre, fat and carbohydrate content were all affected by formulations, but it seems carbohydrates was the most affected. Judging on the extent of variation of the composite bread that ranged from as low as 37.42 to 59.21% carbohydrate while the other food components did not vary that much. The results showed that soaking do not to influence much the chemical composition of the formulated breads.

Generally, it can be concluded that blending will always affect the chemical composition of the composite bread and that the extent of substituting the flour with cassava or cowpea will be judged mostly by acceptability of the product. However, there are other food constituents of the resulting bread that will justify consumers decision to adopt a formulation, for example, nutrient composition or energy content.

Cassava varieties from Mozambique were studied for suitability in pan bread production by substitution of part of the wheat flour with cassava or cowpea or a combination of the two. The results are summarized in Table 13. Moisture content of the bread ranged between 29.50 and 36.04%, lowest value being for the formulation with highest inclusion of cassava and the highest being for formulation with highest content of cowpea (Table 13). Protein content ranged from 8.6 to 14.0%, which was slightly lower than that obtained for the Tanzanian varieties shown in Tables 8-11. Ash and fat content values were comparable to values shown in Tables 8-11 for the Tanzanian varieties. Inclusion of high levels of carbohydrates from cassava or proteins (from cowpeas) was responsible for the striking differences shown in Table 13. High inclusion of cowpeas increased protein, ash and fibre content but diluted the carbohydrate levels in the formulations. Fat content did not show big variation but was again highest in formulation with highest cowpea inclusion. Carbohydrate content was lowest in the 70:30 wheat cassava formulation. This from the fact that carbohydrate content in cowpea is much lower than that in cassava. Table 14 shows composite breads where *Kusse* variety was used. The variation in moisture content of the pan breads was not much (range 29.26 to 36.00%). Ash ranged from 1.10 and 2.19%, which was not much while crude protein as in previous formulation was big (range 8.9-15.0%), being highest in the 70:30 wheat:cassava, in which highest content of cowpea was included. Fat content was generally low, again being high in formulations that had high content of cowpea in the formulation and low in cassava-based composite breads. Crude fibre was highest in cowpea-based formulations. Variation in carbohydrate content was 43.16% in the 70:30 combination involving highest cowpea inclusion and 57.24% in the cassava-based formulation. Generally, the variation between related formulations was not as distinct as was with the Tanzanian varieties.

Table 15 show results for formulations involving *Chinhembue* variety or cowpea or both mixed with wheat flour to form the composite pan bread showed comparable moisture (range 30.00-36.50%), but variable protein content (9.1-15.2%) high in high cowpea formulations and low in high cassava-based formulations. Variation in ash content was not so striking as it ranged between 1.10 and 2.01%. High ash content was in response to high cowpea inclusion in the pan bread formulation. It was also interesting to note that fat content did not show big variation (range 0.48-1.10%), while crude fibre ranged from 1.30 to 2.13% and carbohydrate was 43.06 to 55.68%.

The results of the last cassava variety *Tchicela ni Tchai* composite bread formulation are shown in Table 16. As with the other Mozambican varieties, moisture contents of the formulated breads were similar (range 31.03-36.31%). Similarly, the protein content of the breads were variable (range 9.10-14.7%), but the ash (range 1.10-2.01%) and fat (range 0.56-0.99%) were quite close to each other for the related samples. Just like it was for the other formulations, the fibre content varied (range 1.40-2.60%). Carbohydrate content was between 43.39 and 55.90%. High cowpea formulation had relatively high values of protein, fibre, fat and ash and low values of carbohydrates. The cassava-based formulations on the other hand had more carbohydrate but protein, ash, crude fibre and fat were relatively low when compared with the cowpea-based formulations.

Combining the observations made using the Tanzanian common bread and the Mozambican pan bread it was clear that cassava and cowpea incorporation to make composite bread will play different roles in the product. This has to be understood when an attempt of producing composite bread is being made. Both nutritive value and sensory attributes that eventually influence overall acceptability are affected. However, there are a number of nutritional gains when cowpea is used, e.g., raising the content of protein, ash, and increasing fat retention although this dilutes the carbohydrate content. Cassava, though poor in most nutrients, is rich in energy and can input in increasing energy density of the bread.

4.5.2 Other physical attributes

4.5.2.1 Weights of the bread

Another important parameter that was investigated was the bread weight. The cassava composite bread had the lowest weight followed by the whole wheat bread. Composite bread with 30% cowpea was the heaviest. The weight of loaf bread ranged from 214 to 250 g. The highest value was obtained for 30% cowpea bread and the lowest value was for 5% cassava composite bread. The same was observed in pan type bread with values ranging from 260 to 290g. The lowest value was obtained for 5% cassava composite bread and the highest for 30% cowpea composite bread. The loaf weight increased with increasing amount of cowpea flour substitution indicating that an extra amount of water was retained in breads after baking partly due to binding by cowpea proteins. This result is corroborated by the observation by Rao and Hemamalini (1991). The observed increase in weight with increase in flour substitution is likely to be due to less retention of gas in the blended dough that provide denser bread texture as explained by Sharma (2000).

4.5.2.2 Loaf volume

The whole wheat bread and 5% cassava composite bread had a similar loaf volume and good shape, while the 10%, 15% and 20% substitution had a little reduction in loaf volume and irregular shape. The 30% substitution produced more reduction in loaf volume and the resulting bread had very irregular shape. The loaf bread size ranged from 560 ml for 30% cowpea bread to 890 ml for 100% wheat bread. The same phenomenon was seen in pan bread, where the loaf size ranged from 420 to 620 ml. As usual, the highest value was observed for whole wheat bread and the lowest for 30% cowpea composite bread. As the level of cassava is increased in the formulation there is a corresponding decrease in loaf volume (Fig. 5).

The same situation was encountered, for cowpea inclusion in the formulations. When cassava and cowpea were included together in a formulation, still there was a corresponding decrease in loaf volume. When the ratio of cassava-cowpea was reversed, the loaf volume seem not to be affected. For improvement of nutritive value of the bread, more cowpea than cassava needs to be used. The dilution effect on gluten with the addition of either cassava or cowpea flour to wheat flour caused less retention of CO_2 gas resulting in depression of loaf volume as also observed by Sharma (2000) and Chauhan *et al.* (1992). The mean loaf volume scores for Tanzania and Mozambican breads were not significantly different up to 15% cassava or cowpea composite bread ($p \geq 0.05$) but were statistically different for 20% cassava or cowpea composite bread ($p \leq 0.05$). However, there was no significant influence of either variety, soaking or not soaking ($p \geq 0.05$).

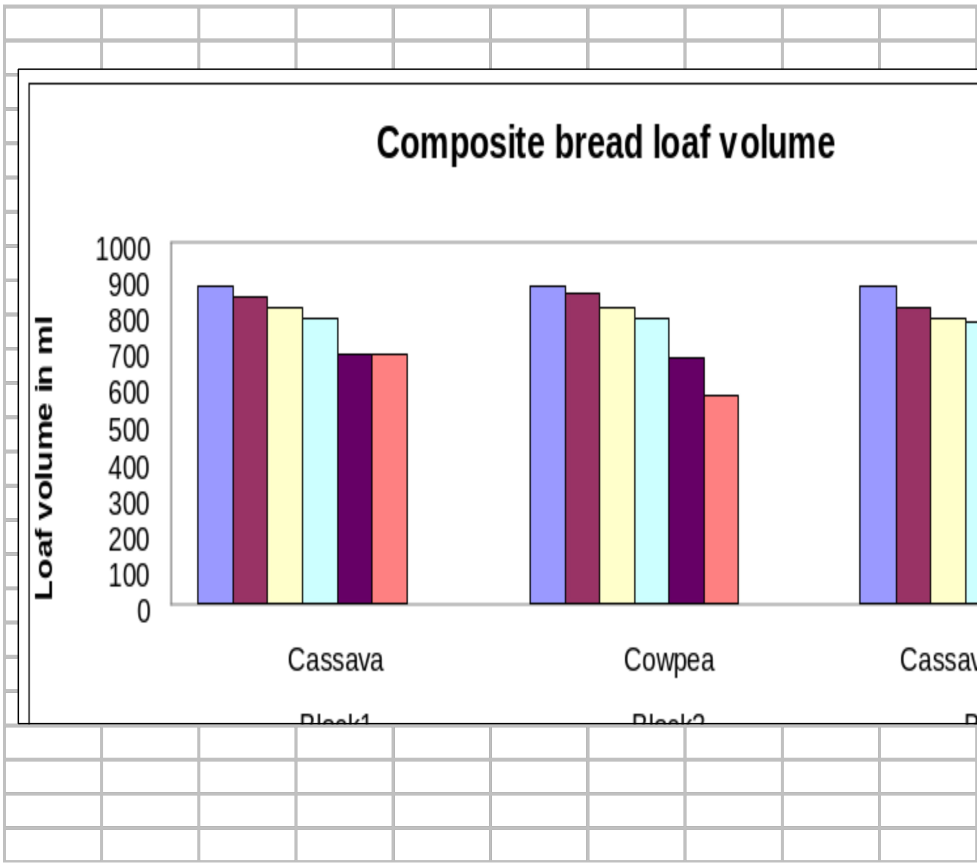


Figure 5: Effect of substitution of wheat with cassava/cowpea on bread loaf volume

4.5.2.3. Bread specific volume

Specific volume of the loaf ranged from 2.39 to 4.07ml/g. The highest value was obtained for 5% cassava bread and the smallest value was observed for 30% cowpea composite bread. The same was observed in pan bread type, where the values ranged from 1.45 to 2.31. The highest value was for 5% cassava composite bread. It was observed that as dilution was decreased, more weight of bread was found in cm^3 volume (en.wikipedia. org/wiki/ Specific_volume). The specific volumes between the types of composite breads were not significantly different ($p \geq 0.05$). But there was significant differences within bread formulations ($p \leq 0.05$). There was a decrease in specific loaf volume on increasing the levels of either cassava or cowpea. The specific volume shows the relationship between solids and air fraction in the bread. Bread with low specific volume is not well accepted by consumers and is associated with high moisture content leading to low shelf life, low aeration, and difficulties in chewing as reported by Esteller and Lannes (2005). The poor quality and quantity of gluten in composite blended breads may be responsible for low retention of CO_2 gas in the fermented dough and low specific loaf volume (Dhingra *et al.*, 2002). In both countries either cassava varieties or soaking and not soaking did not influence the breads specific volumes significantly ($p \geq 0.05$).

4.5.2.4 Baking losses

It was evident that whole wheat bread and 5% composite bread had lower losses after baking followed by 10% composite bread, up to 30% cowpea composite bread in both types of bread (Fig. 6). Results showed that as more cowpea was added, the losses increased. This implies that as the level of gluten decreased losses decreased. The baking losses ranged from 5 to 14.18%. The lowest value was for 30% cowpea composite bread, which showed small losses in terms of dough moisture while in 5% cassava composite bread, losses were highest showing that more water was lost through evaporation during baking. This situation was also observed in pan bread where the losses ranged from 3.33 to 13.30%, the highest value being for 5% cassava composite bread and the lowest for 30% cowpea composite bread. In cowpea composite bread an extra amount of water was retained that, increased the weight of bread. This was probably because the high protein content had the ability to retain more water than in the other samples as observed by Laird (2005) in soyabean composite bread.

Figure 6: Baking losses as observed for different bread formulations

In Tanzania, there was statistical difference ($p \leq 0.05$) among the bread scores, baking losses in the different formulations. Either cassava variety or soaking or not soaking did not influence the breads baking losses ($p \geq 0.05$). For the Mozambican samples the situation was similar.

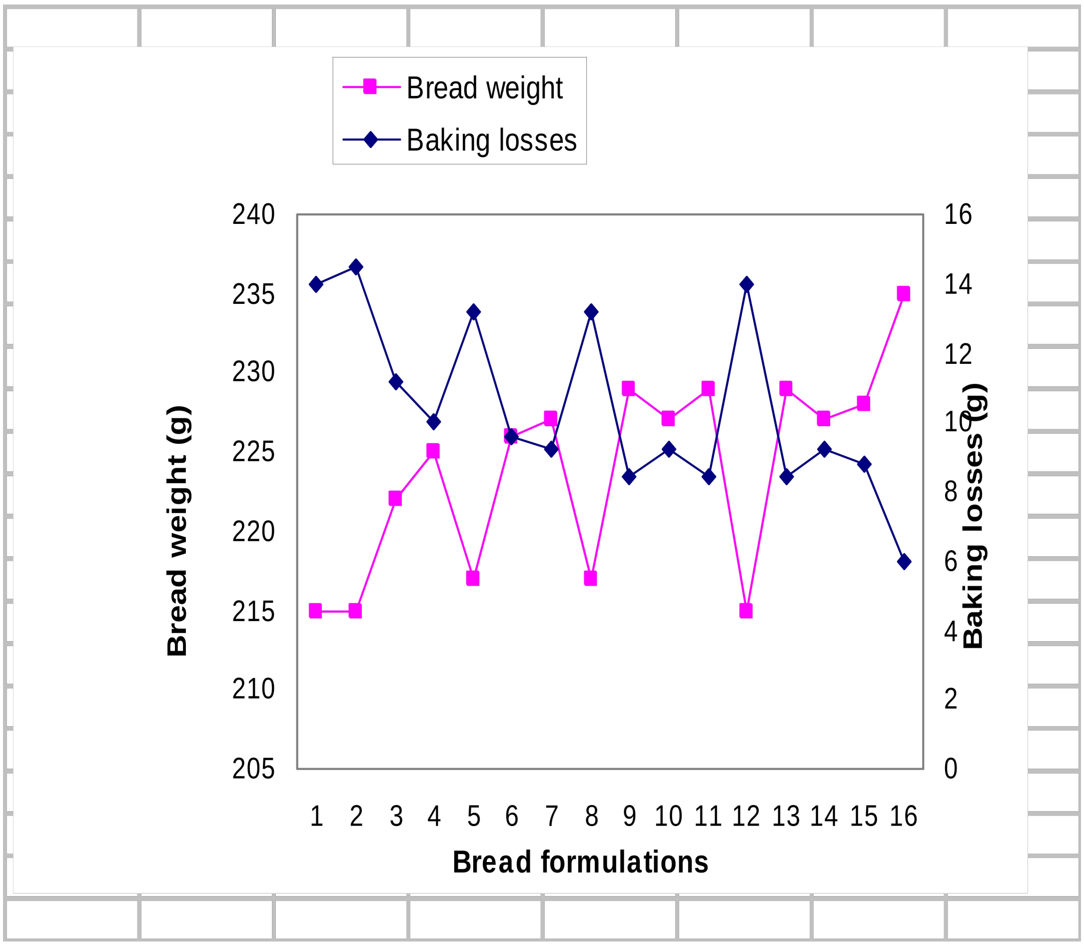


Figure 7: Relationship between bread weight and baking losses

4.6 Bread shelf life

The shelf life study was done only in Mozambique. The shelf life of the breads were as follows: Breads control (whole wheat bread) had a shelf life of four days recorded when stored in plastic package. Breads stored without wrapping material lasted longer, but dried fast. The cassava composite bread lasted longer. For example 20% cassava bread kept in plastic bags lasted six days. On the other hand, the cowpea composite bread lasted shorter, with the 30% cowpea composite bread maintaining shelf life for only two days.

4.7 Quality assuarance and bread cyanogen content

Composite flour was processed under well-designed Quality Assurance program which prevented the flour from all kinds of contamination. All potential hazards in cassava and cowpea were taken care of, during processing so as to remove as much as possible the cyanogens, prior to its substitution to the wheat flour, for composite flour production. Also, the breads were analyzed and no cyanogens was found. The processed flour was relatively low in moisture content, which did not facilitate mould and bacterial growth ou toxin production. Hygiene was assured in all stages from cassava drying process up to bread making. During baking at high temperature cyanogens are removed from the dough as explained by Edward (1974) and Oluwole *et al*. (2006), which led to no cyanogens presence in any of the breads prepared from the cassava based flours.

4.8 Socio-economic aspects

The use of composite flours in bakery products offers better opportunities to reduce imports of wheat thereby improving the foreign exchange reserves. In Mozambique, bread consumption is expanding and there is increasing dependence on imported wheat. Mozambicans may dilute wheat flour with locally available cereals and a root crop to encourage the growth in agricultural sector and reduce wheat imports. Thus, composite flour technology holds promise for Mozambique and Tanzania. Dilution of wheat flour in bread making may reduce production costs and bread price made affordable by the common man in Mozambique. Substitution of wheat with cowpea flour in bread making may reduce malnutrition as cowpea improves the nutritional value of the bread. Prospects for commercial production and utilization of locally produced crops will increase farmers income and may lead to reduction in food insecurity. Furthermore, there are other benefits like reduction of huge post-harvest losses experienced by farmers and increase in their output due to available market, thereby enhancing farmer’s income. More jobs will also be created and the nations will be better in terms of food security, as documented by FIIRO (2005). Mozambique is trying to produce its own wheat in Angonia plateau, in Tete province, where a small amount of wheat is produced. This amount is too small for the country`s needs. Reports show that Mozambique is expected by the year 2014/15 to produce 50 percent of the wheat that it consumes (Agencia de Informação de Moçambique, 2008). Integration of cassava and/or cowpea in wheat based can greatly reduce the wheat deficit that was to be imported into the country.

The cost of wheat in the world market rose dramatically last year (2007), partly because of climatic factors, such as a crippling drought in one of the main wheat producers, Australia, and partly due to farmers switching from food crops to biofuels (http://www.Financial speculators reap profits from global hunger). The world wheat production has decreased from 2006 to 2008 and as a result the wheat price has risen by 136% (http://www.Financial speculators reap profits from global hunger).

It is timely to promote production of composite bread in Mozambique so as to save foreign exchange, which is spent on purchasing wheat. There is urgent need of substitution of wheat flour with cassava flour or other locally available crops so as to reduce the amount of the country`s wheat import bill, which needs 450.000 tonnes of wheat to satisfy populations needs (Agencia de Informação de Moçambique, 2008). Considering the wheat price in February 2008, the country must spend something like USD 295,117.200 in foreign exchange but using composite bread up to 15% Mozambique can be able to save USD 44 267 580 of foreign exchange.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The proximate analysis of cassava composite bread was slightly different from that of 100% wheat bread. The cowpea composite bread had increased protein content in comparison with whole wheat bread. It was found that the cassava composite breads (including as high as 20% cassava) was not significantly different in most sensory attributes when compared with whole wheat bread, in protein and some other nutrient composition. In pan bread, cassava-based composite bread needed more baking time than the whole wheat bread to get the golden colour of the crust. If widely accepted, composite bread may be viable alternative to achieve the desired economic, food security and healthy community in Mozambique. The most appealing bread in pan type was 5 and 10% cowpea composite bread. The 5 and 10% cowpea composite bread can be used as a colour improver in addition to the improvement in nutrient composition in pan type bread. Bread baked from 30% cowpea based composite flour was the most nutritious bread in all aspects. The formulations were best when composite flours were as high as 15% cassava or cowpea composite flours. Bread weight, loaf volume and specific volume were acceptable. Beyond 15% there were changes in sensory attributes. It was likely that beyond 15% composite flour binding agents must be added. The cassava varieties used in this study had the same effect on bread making. More research need to be done to improve the composite bread. The price of bread, involving the non-wheat flours will be relatively, low because such flours will be locally produced, thus making many households afford the composite bread. Incorporation of cowpea will assist in improving nutrient composition while increased use of cassava in the formulation can contribute to sustainable improvement of food security as it will favour more production of cassava in the country.

5.2 Recommendations

From this study, 5, 10, 15 and 20% cowpea composite flour can be used to produce bread that is good in terms of colour and has increased nutrient content and is thus recommended for promotion to increase cowpea use in the country.

Also, given the high cost of wheat, cassava could also be used in composite flour formulation and the nutrient content could be improved by blending it with cowpea at levels not exceeding 20% of non-wheat material blend.

In places hit by malnutrition the inclusion level of not exceeding 30% legume could be used to benefit the victims as it can still produce acceptable bread, although acceptability will decrease with increase of cowpea in the blend

In view of the reduced loaf volume due to low gluten when composite flour is used there is a need for futher studies.

REFERENCES

Agencia de Informação de Mocambique (2008). (Mozambique Information Agency) [http://www.allafrica. com/ stories /200804 0208 89. html] site visited on 14/6/2008.

Abolaji, D.D., Willie, O.S., Oladele, O.A. and Isiaka, A.O. (2007). Capacity Innovations in Cassava Production, Harvesting and Processing in Nigeria. National Centre for Technology and Management, Federal Ministry of Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria. pp200.

Ajibola, O., Aviara, N.A. and Ajetumobi, P. (2003). Sorption equilibrium and thermodynamic properties of cowpe. *Journal of Food Engineering* 58(6):317-324.

Ayo, J.A. (2003). Effect of *Amanranthus* grains flour on the quality of biscuits. *International Journal of Food Properties* 3:45-72.

Badrie, N. and Mellowes, W.A. (1992). Cassava starch or amylose effects on characteristics of cassava (*Manihot esculenta Crantz*) extrudate. *Journal of Food Science* 57(1):103-107.

Barbano, D.M., Clark, J.L., Dunham, C.E. and Fleming, J.R. (1990). Kjeldahl method for determination of total Nitrogen content of milk: collaborative study. *Journal of Association of Official Analytical Chemists* 73: 849-859.

Basman, A., Koksel, H. and Ng, P.K.W. (2003). Utilization of transglucanase use to increase the level of barley and soy flour incorporation in wheat flour breads. *Journal of Food Science* 68(8):2453-2460.

Bradbury, J.H. and Holloway, W.D. (1988). Chemical of tropical Root Crops: Significance for Nutrition and Agriculture in the Pacific. ACIAR Monograph nº 6, Australian Centre for International Agricultural Research, Canberra, pp 26.

Bradbury, M.G., Egan, S.V. and Bradbury, J.H. (1999). Picrate Paper Kits for Determination of Total Cyanogens in Cassava Roots and All forms of Cyanogens in Cassava Products. Canberra, Australia. 593pp.

Food Research International (2007). Bread ingredients [http://www.answers .com/ topic /bread] site visited on 20/11/2007.

Bressani, R. (1985). *Nutritive Value of Cowpea*. Instituto de Nutricion de Centro America y Panama (INCAP), Guatemala. 360pp.

Carnovale, E., Marletta, L., Marconi, E. and Brosio E. (1990). Nutritional and hydration properties in cowpea. In: *Cowpea Genetic Resources*. (Edited by Ngumi, N.O. and Monti) L.M., International Institute of Tropical Agriculture. Lagos. pp 113-141.

Southern Africa Biotechnology Program (2004). Pest and constraint to cassava production in southern Tanzania and northen Mozambique. [http://www. cassavabiz. org/production/virus02.htm] site visited on 3/6/2008.

Centre for the Development of Industry (1997). Small bakeries and the valorization of local cereals in ACP countries. Food and Nutrition Library, working paper 2. Oshodi, Nigeria. 80pp.

Chauhan, G.S, Zillman, R.R. and Eskin, N.A.M. (1992). Dough mixing and bread making properties of quinoa-wheat flour blends. *International Journal of Food Science and Technology* 27:701-705.

Chrissie, R. (2006). Cassava research project. Improvement of cassava for social and economic benefits. [http://www.africancrops.net/rockefeller /crops/cassava/ index. htm] site visited on 3/6/2008.

Institut of Tropical Agriculture (2007). Nutritive value of cassava. [http://www.unu .edu/unupress/food/8F024e/8F024E01.htm] site visited on 24/3/2008.

Cook, J.H. (1985). *Cassava, A Basic Energy Source in the Tropics*. Tropical Science, Lagos, Nigeria. 762pp.

Southern Africa Biotechnology Program (2006). Constraints to cassava production in sub-Saharan Africa. Cassava mosaic disease in Mozambique. [http://www. saspp.org/content/view/60/11/] site visited on 03/06/ 2008.

Institute of Tropical Agriculture (2003). Cowpea production. [http://www. African crops. net/rockefeller/crops/cowpea/ index] site visited on 03/06/2008.

Cunningham, M. (Eds) (1990). *The Fannie Farmer Cookbook*. 13 edition, New York. 230pp.

Czuchajowska, Z., Pomeranz, Y. and Jeffers, H.C. (1989). Water activity and moisture content of dough and bread. *Journal of Cereal Chemistry* 40(3):66-128.

De Floor, I. and Delcour, J. A. (1993). Impact of milling procedure on bread making potential of cassava flour in wheatless bread. *Journal of Cereal Chemistry,* 70(5): 616-617.

Dendy, D.A.V. (1992). Composite flour - past, present and the future: a review with special emphasis on the place of composite flour in the semi-arid zones. In: *Utilizution of Sorghum and Millets. (Edited by L.R. Gomez, L.W. House, Rooney and D.A.V. Dendy)*. Patancheru, India. pp 67-73.

Dgis, E. (1991). *C*assava and biotechnology. In *Proceedings of the workshop, (Edited by Directorate General for International Co-operation)*. Amsterdam, 21-23 March, 1990, Amsterdam. 23.37pp.

Dhingra, S. and Jood, S. (2002). Physico-chemical and nutritional properties of cereal-pulse blends for bread making. *Nutrition and Health Journal* 16(3): 94-18.

Edward, D. (1974). *The Industrial Manufacture of Cassava Products. An Economic Study.* Tropical Products Institute, London. 400pp.

Eliasson, A.C. and Larsson K. (1993). *Cereals in Bread Making. A Molecular Colloidal Approach* and *Food Technology*. Chemical Center, University of Lund, Sweden. 309pp.

Esteller, M.S. and Lannes, C.S. (2004). Complementary parameters of requirements to fixing identity and quality of bakery products. [http://www.scielo.br/scielo.php? script=sci_arttext&pid=S0101-20612 005000 4000 2 8] site visited on 20/2/2008.

Food and Agricultural Organization (1987). Cassava in composite flour. Cassava processing: FAO plant production and protection. [http://www:Fao.org /DOCREP/x0818e /x5032 E00.htm] site visited on 17/05/2007.

Food and agricultural Organization (1989). *Roots, Tubers and Plantains: Food Security in Sub-saharan Africa and Carribbean in Pacific. Annual Report*. Food and Agriculture Organization, Rome, Italy. 20pp.

Food and Agricultural Organization (1995). Sorghum and millet in human nutrition. [http://www.fao. org/DOCREP/T 0818e/ T0818 E00] site visited on 10/09/2005.

Food and Agricultural Organization (1998) *Food Outlook. Annual Report.* Food and Agriculture Organization, Rome. 40pp.

Food Agricultural Organization (2001). *The State of Food Insecurity in the World. Annual Report*. Food and Agriculture Organization, Rome. 80pp.

Food and Agricultural Organization (2007). About mold bread [msed.iit.edu/ ids/ curriculum/ biology/model_lessons/Unit_6_BreadMold] site visited on 14/05/2008.

Food and Agricultural Organization (2002). The global cassava development strategy and implementation. [http://www.fao.org/documents/ show cdr.asp?url file =/docrep / 006/y0169e /y016 9e00.htm] site visited on 14/3/2005.

Federal Institute of Industrial Research (2005). Cassava-wheat flour and composite bread production. [http://ww w.fiiro.federal institute of industrial research, oshodi, nigeria (fiiro).htm] site visited on 14/3/2008.

San Francisco Bread Review (2006). French bread (2006). [http:www.french bread.free.fr/] site visited on 20/11/2008.

Giami, S.Y., Amasisi, T. and Ekiyor, G. (2004). Comparison of bread making properties of composite flour from kernels of roasted and boiled African breadfruit (Treculia Africana decne) seeds. *Journal of Raw Material Resources* 1: 16–25.

Hahn, K. (1989). An overview of African traditional cassava processing and utilization. *Outlook on Agriculture* 18 (3): 5-10.

Hallén, E., Ibanoglu, S. and Ainsworth, P. (2004): Effect of fermented/germinated cowpea flour addition on the rheological and baking properties of wheat flour Department of Food Science, Swedish University of Agriculture Science, 75007, Uppsala, Sweden. *Journal of Food Engineering* 63 (2):177-184.

Heemskerk, W. (1985). *Cultura de Feijão Nhemba, Série Agricultura, Ministério da Agricultura*, (Cowpea cultivation, Agriculture, Ministry of Agriculture), Maputo, Mozambique. 79pp.

Herbst, S.T. (1997). *The Food Lovers Companion*; *2nd edition*. Barron Education Services Inc., London. 250pp.

Holas, J. and Tripples, K.H. (1978). Factors affecting farinograph and baking absorption . *Journal of Cereal Chemistry* 9(3):565-637.

Hooda, S. and Jood, S. (2005). Effect of fenugreek flour blending on physical, organoleptic and chemical characteristics of wheat bread.´*Journal of Nutrition and Food Science* 35 (4): 229-242.

Hoseney, C.R. (1994). Principles of Cereal Science and Technology. *American Association of Cereals Chemistry* 12(6):789-810.

William J. Murphy (2006). Bushel wheat in 1 ton (2005). [http://www.wiki.answers .com/Q/How_ many _ bushel_ equals_ to_1_ton] site visited on 5/7/2008.

Hsieh, H.H., Pomeranz, Y. and Swanson, B.G. (1992). Composition, cooking time, and maturation of akuzi (Vigna angularis) and common beans (Phaseolus vulgaris). *Journal of Cereal Chemistry* 69 (3):244-248.

Hugo L.F., Rooney L.W. and Taylor J.R.N. (2003). Fermented sorghum as a functional ingredient in composite breads. *Journal of Cereal Chemistry* 80: 495-499.

Ihekoronye, A.I. and Ngoddy, P.O. (1985). *Integrated Food Science and Technology only for the Tropics*. McMillan Publishers, Lagos. 291pp.

International Institute of Tropical Agriculture (2006). CMD causes in Malawi, Mozambique and South Africa. [http://www.iia.msu.edu/project_sabp.html] site visited on 3/7/2008.

International Institute of Tropical agriculture (2005). Portuguese colonists and their African descendants in Mozambique and the diffusion of cassava crop in the lower Zambezi. [www.iita.org/cms/ details /trn_mat/irg49/irg494.html] site visited on 14/05/2008.

Instituto de Investigação Agronómica de Moçambique (2006). Cultivo de mandioca (Cassava crops). Ministry of Agriculture, Maputo, Mozambique. 20pp.

International Starch Institute (2005). Determination of Crude Fibre. [http://www .starch.dk/isi/metho ds/crude fibre.htm] site visited on 12/10/2007.

Jacob, H.E. (1997). *Six Thousand Years of Bread. Its Holy and Unholy History*. Lyons and Burford, New York. 300pp.

International Institute of Tropical Agriculture (2006). Cassava types. [http://www. unu.edu/unupress/food /8F024e/ 8F024E01 .htm] site visited on 10/1/2008.

Kure, O.A., Bahago, E.J. and Daniel, E.A. (1998). Studies on the proximate composition and effect of flour particle size on acceptability of biscuits produced from blends of soyabeans and plantain flours. *Namoda Technology Scope Journal* 3(2): 68-72.

Kussaga, J. (2007). Starch. whole wheat and composite breads. Dissertation for award of MSc degree at Sokoine University of Agriculture, Morogoro, Tanzania. 90pp.

Laird, J. (2005). Injecting a protein boost. Baking Management. Buyer`s guide. [http://www.baking-management.com/ingredients/bmimp_7996/] site visited on 17/09/2008.

Lorraine, L.N. MSc and Fatimah, L.C. J. (2000). Tapioca root and tapioca flour: consumption and potential. Dissertation award of MSc and PhD degree at Department of Nutrition and Food Science and Department of Anthropology at University of Maryland, College Park, Oregon State of America. 99pp

Cereal Research Institute (2005). French bread (2005). [http://www.baking911. com / bread/french.htm] site visited on 11/11/ 2007.

Mejía, D. (2003). Maize: Post-harvest operation. [http://www.fao.org/ inpho] site visited on 20/12/2007.

Ministerio da Agricultura (2006). *Evolução das áreas semeadas*. (Evolution of cultivated areas. Annual Report. Ministerio da Agricultura, Maputo, Mozambique. 25pp.

Mtebe, K. and Karegero, M.M. (1994). Acceptability of wheat-sorghum composite flour products. Plant Foods. *Journal of Human Nutrition* 46(4):305-12.

Naureen, S. (2004). Use of composite flour for chapatti preparation in relation to serum profile. A dissertation for Award of Doctor of Philosophy in Food Technology at University of Agriculture, Faisalabad, India, 100pp.

Nestel, B. and Cock, J. (1980). The development of an international research network. *International Institute of Tropical Agriculture*, Ibadan, Nigeria 6:14-7.

Official Methods of Analysis (1995). Quality in products [http://www.half.com product.half.ebay.com/-WOQQprZ2101155] site visited on 12/8/2005.

Okigbo, B.N. (2008). Nutritional implications of projects giving high priority to the production of staples of low nutritive quality: the case for cassava (*Manihot esculenta, crantz*) in the Humid Tropics of West Africa. *International Institute of Tropical Agriculture*, Ibadan, Nigeria 7:245-264.

Olaoye, O.A.; Onilude, A.A. and Idowu, O.A. (2006). Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. *African Journal of Biotechnology* 9 (7):1102-1106.

Oluwole, O. Onabolu, A.O. and Akobundu, U.E. (2006). Bread making technology and ingredients for bread making. A paper presented at a training workshop on the use of cassava/wheat composite flour and non-bromate additives making bread and other confectioneries. Held at 2-4 November (2006), Michigan. Okpara University of Agriculture, Michigan., USA. 45-60pp.

Okaka, J.C. and Isieh, M.I. (1990). Development and quality evaluation of cowpea wheat biscuits. Niger. *Food Science Journal* 8(5):56–62.

Oyenuga, V.A. (1972). Nigeria's Food and Feeding Stuffs. *University of Ibadan Press*, Ibadan, Nigeria 5(3):120-143.

Food security Pack Project (2005). Sensory evaluation of composite bread . *Journal of food Science*, Lusaka, Zambia 7(5):230-252.

Pelembe, L.A.M. (2001). Increase food utilization of beans and cowpeas in East and Southern Africa. [http://www.isp.msu.edu/CRSP/ESAFY yo6 Highlights.Pdf] site visited on 12/6/2007.

Phuc, B.N., Ogle, B. and Lindeberg, J.E. (2000). Effect of replacing soybean protein with cassava leaf in cassava root based diets for growing pigs on digestibility and N retention. *Journal of Animal Feed Science and Technology* 8(4):223-235.

Pomeranz, Y. and Meloan, C.E. (1992). *Food Analysis, Theory and Practice*. *Third Edition*. Chapman and Hall editors, New York. 626pp.

International Institute of Tropical Agriculture. Portuguese roll baking oven in Mozambique (2004). [http:// www.repp.org/.../ resource.stoves/Scott/mozamb ique/Portugese %20Roll%20baking% 20Oven%20In %20Mozambique.pdf] site visited on 12/01/2008.

Raidi, M.A. and Klein, B.P. (1983). Effect of soy or field pea flour substitution on physical and sensory characteristics of chemically leavened quick breads. *Journal of Cereal Chemistry* 60(9): 367–370.

Raja, K.C.M. and Ramakrishna, S.V. (1990). Compositional and pasting characteristics of plain-dried and parboiled cassava (*Manihot esculenta crantz*). *Journal of Food Chemistry* 38(5): 79-88.

Rao, H.P. and Hemamalini, R. (1991). Effect of incorporating wheat bran on rheological characteristics and bread making quality of flour. *Journal of Food Science and Technology* 28(3): 92–97.

Samuel, D. (2000). Brewing and Baking". *Ancient Egyptian Materials and Technology.* P.T. Nicholson and I. Shaw, Cambridge University Press, Cambridge. 400pp.

SARRNET (2003). *Multiplicação Acelerada e Distribuição de Materiais de Plantio Saudáveis das Melhores e mais Produtivas Variedades de Mandioca e Batata Doce em Moçambique*, (Hasten Multiplication of Cassava and Sweet Potatoes High Yield Varieties). Instituto Internacional de Agricultura Tropical, Ibadan Nigeria. 130pp.

Scott, G.J., Rosegrant, M.W. and Ringler, M.W. (2000). Roots and Tubers for 21 century trends, projections and policy options. In: Proceedings of Food Agriculture and the Environment. Discussion paper 31. Edited by International Food Policy Research Institute, 6-9 July 2000, Ibadan, Nigeria. 110-123pp.

Sharma, K. (2000). *Rheological and Baking Characteristics of Some Wheat Varieties.* International Institute of Tropical Agriculture, Nigeria. 300pp

Shittu, T.A. Raji, A.O and Sanni, L.O. (2005). Bread from composite cassava wheat flour: Effect of baking time and temperature on some physical properties of bread loaf. *Journal of Food Science and Technology* 8(3):123-133.

Singh, S.R. and Jackai, E. N. (1985) Insect pests of cowpeas in Africa: Their life cycle, economic importance and potential for control. *International Institute of Tropical Agriculture* 7(4):216-231.

Singh, S.R. and Rachie, K.O. (1985). Cowpea research, production and utilization. *International Institute of Tropical Agriculture* 8(5):353–371.

Food Policy Institute (2004). Bread specific volume. [http://www.en.wikipedia. org/wiki/ Specific_volume] site visited on 6/6/2008.

Spiekermann, U: (2006). Brown Bread for Victory: German and British Wholemeal Politics in the Inter-War Period. In: *Food and Conflict in Europe in the Age of the Two World Wars*. Trentmann Frank and Just. (Edited by Flemming), New York. pp360-387.

Summerfield, R.J. and Bunting, A.H. (1980). Advances in legume sciences. In: *Proceeding of the International Legume Conference*, Vol 1, 31 July – 4 August 1978, Royal Botanic Garden, Kew, the Missouri Botanical garden and the University of Reading. 200-215pp.

Tannahill, R. (1973). *Food in History*. (Edited by Stein and Day) New York, USA. 227pp.

International Cereal Institute (2006). Bread and flour regulation. [http://www.en. wikipedia.org/wiki /Flour# Wheat_flour] site visited on 20/6/2008.

Tivana, L.D. and Bvochora, J. (2005). Reduction of cyanogenic potential by heap fermentation of cassava roots. Cassava cyanide diseases network news, issue number 6. p12.

Trager, J. (1995). *The Food Chronology: a Food Lover's Compendium of Events and Anecdotes from Prehistory to the Present*. (Edited by Henry Holt).New York. 273pp.

International Food Policy Institute (2008). Bread types [http://www. breadchef. com.au/types-of-bread.html] site visited on 20/11/ 2007.

United States Agency for International Development (2007). Wheat flour production [http://www.Finantial speculators.reap.profits.from global hunger] site visited on 6/6/2008.

Westby, A. (2002). Cassava utilization, storage and small-scale processing. *Journal of Tropical Science* 3:89-100.

International Institute for Tropical Agriculture (2005). World cowpea production. [http://www.cowpea.org/node/] site visited on 12/6/2008.

APPENDICES

Appendix I: Sensory evaluation sheet

Please choose the term that best reflect your attitude towards the products by writing a number under the product code. Test the sample from left to right.

Name…………………………………….Date………………….Sex……………

CODE	**512**	**402**	**115**	**204**	**300**	**314**
COLOUR 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
AROMA 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
LOAF VOLUME 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
TASTE 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
GENERALL ACCEPTABILITY 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
BUYING PREFERENCE 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						

Comments……………………………………………………………………………….

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Appendix I: Sensory evaluation sheet

Please choose the term that best reflect your attitude towards the products by writing a number under the product code. Test the sample from left to right.

Name………………………………….Date………………….Sex……………

CODE	421	305	522	403	210	500
COLOUR 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
AROMA 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
LOAF VOLUME 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
TASTE 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
GENERALL ACCEPTABILITY 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
BUYING PREFERENCE 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						

Comments……………………………………………………………………………….

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Appendix I: Sensory evaluation sheet

Please choose the term that best reflect your attitude towards the products by writing a number under the product code. Test the sample from left to right.

Name………………………………….Date………………….Sex……………

CODE	**390**	**526**	**354**	**230**	**423**	**388**
COLOUR 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
AROMA 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
LOAF VOLUME 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
TASTE 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
GENERALL ACCEPTABILITY 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						
BUYING PREFERENCE 5 = Like very much 4 = Moderately 3 = Neither like nor dislike 2 = Dislike moderately 1 = Dislike very much						

Comments……………………………………………………………………………….

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Appendix II: Baking losses in composite breads, Morogoro, Tanzania

Formulations	Composition	Unsoaked cassava bread				Soaked cassava breads			
	Wht:cas:cow*	Kiroba (ml)	Mzuri.Kwao (ml)	Mumba (ml)	Kigoma (ml)	Kiroba (ml)	Mzuri.Kwao (ml)	Mumba (ml)	Kigoma (ml)
1	100:0:0	14.0	16.6	14.0	13.87	14.0	13.6	13.2	13.2
2	95:5:0	14.5	14.6	14.4	14.1	14.4	14.0	14.4	14.4
3	95:0:5	11.2	12.8	12.0	12.4	12.0	12.0	11.6	12.0
4	90:0:10	10	10	9.6	9.6	10	9.6	9.2	10.0
5	90:10:0	13.2	14.0	14.0	14.0	12.8	13.6	14.0	13.2
6	90:5:5	9.6	9.2	10.0	10.0	9.2	9.6	10.0	9.6
7	95:0:15	9.2	8.8	8.8	8.4	9.2	8.8	8.4	8.4
8	95:15:0	13.2	13.6	14	14	14	14	13.6	13.2
9	85:5:10	8.4	8.8	8.4	9.2	9.2	8.4	8.8	8.8
10	85:10:5	9.2	8.4	12.0	9.8	12.4	8.8	8.4	8.0
11	80:0:20	8.4	8.8	8.8	8.8	8.8	9.2	8.4	8.8
12	80:20:0	14	13.2	13.6	13.6	13.6	13.2	14.0	13.6
13	80:5:15	8.4	8.0	8.8	8.4	9.2	8.4	8.8	8.8

14	80:15:5	9.2	8.0	9.6	8.8	8.0	8.8	8.8	9.2
15	80:10:10	8.8	9.2	8.8	8.4	8.4	8.0	8.0	8.4
16	70:0:30	6.0	8.0	6.0	6.8	6.0	8.0	5.6	7.2

*Wht:cas:cow-wheat:cassava:cowpea

Appendix III: Bread weight of composite bread, Morogoro, Tanzania

Formulations	Composition		Unsoaked cassava bread				Soaked cassava breads		
	Wht:cas:cow*	Kiroba (g)	Mzuri.Kwao (g)	Mumba (g)	Kigoma (g)	Kiroba (g)	Mzuri.Kwao (g)	Mumba (g)	Kigoma (g)
1	100:0:0	215	216	215	215	215	216	217	217
2	95:5:0	215	215	214	215	214	214	214	214
3	95:0:5	222	218	220	219	220	220	221	220
4	90:0:10	225	225	226	226	225	226	227	225
5	90:10:0	217	215	215	215	218	216	215	217

6	90:5:5	226	227	225	225	227	226	225	226
7	95:0:15	227	228	228	229	227	228	229	229
8	95:15:0	217	216	215	215	215	215	216	217
9	85:5:10	229	228	229	227	227	229	228	228
10	85:10:5	227	229	220	225	225	228	229	230
11	80:0:20	229	228	228	228	228	227	229	228
12	80:20:0	215	217	216	216	216	217	215	216
13	80:5:15	229	230	228	229	227	229	228	228
14	80:15:5	227	230	226	228	230	228	228	227
15	80:10:10	228	227	228	229	229	230	230	229
16	70:0:30	235	230	235	233	235	230	236	232

*Wht:cas:cow-Wheat:cassava:cowpea

Appendix IV: Bread weight and baking losses, Maputo, Mozambique

Formulations	**Composition Wht:cas:cow***	**Nhambatsana**		**Chinhembue**		**Tchicela ni tchai**		**Kusse**	
		Bread weigh (g)	**Baking losses (g)**	**Bread weigh (g)**	**Baking Losses (g)**	**Bread weigh (g)**	**Baking losses (g)**	**Bread weigh (g)**	**Baking losses (g)**
1	100:0:0	270.00	10.00	270.00	10.00	265.00	11.67	265	11.65
2	95:5:0	266.00	11.33	265.00	11.67	270.00	11.0	268.00	11.33
3	95:0:5	273.00	9.00	273.00	9.00	273.00	9.00	272.00	9.00
4	90:0:10	274.00	8.67	274.00	8.67	275.00	8.33	275.00	8.56
5	90:10:0	270.00	10.00	270.00	10.00	272.00	9.33	272.00	9.78
6	90:5:5	274.00	8.67	275.00	8.33	273.00	9.00	274.00	8.67
7	95:0:15	274.00	8.67	275.00	8.33	274.00	8.67	279.00	8.56
8	95:15:0	265.00	11.67	268.00	10.67	265.00	11.67	265.00	11.67
9	85:5:10	278.00	7.33	278.0	7.33	279.00	7.00	279.00	7.22
10	85:10:5	278.00	7.33	279.00	7.00	279.00	7.00	278.00	7.11
11	80:0:20	279.00	7.00	279.00	7.00	278.00	7.33	278.00	7.11
12	80:20:0	270.00	10.00	270.00	10.00	265.00	11.67	270.00	10.56
13	80:5:15	278.00	7.33	278.00	6.67	278.00	7.33	278.00	7.33

14	80:15:5	279.00	7.00	274.00	8.67	279.00	7.00	277.00	7.56
15	80:10:10	278.00	7.33	279.00	7.00	278.00	7.33	278.00	7.22
16	70:0:30	28200	6.00	284.00	5.33	280.00	6.67	282.00	6.00

*Wht:cas:cow-Wheat:cassava:cowpea

Appendix V: Specific volume of composite bread, Morogoro, Tanzania

Formulations	Composition	Unsoaked cassava bread				Soaked cassava breads			
	Wht:cas:cow*	Kiroba (ml/g)	Mzuri.Kwao (ml/g)	Mumba (ml/g)	Kigoma (ml/g)	Kiroba (ml/g)	Mzuri.Kwao (ml/g)	Mumba (ml/g)	Kigoma (ml/g)
1	100:0:0	4.09	4.07	4.13	4.10	4.09	4.07	4.03	4.08
2	95:5:0	3.95	4.0	4.07	4.00	4.04	4.04	4.02	4.02
3	95:0:5	3.87	3.99	3.95	3.93	3.95	3.93	3.93	3.90
4	90:0:10	3.64	3.67	3.72	3.65	3.64	3.63	3.66	3.67
5	90:10:0	3.78	3.86	3.84	3.81	3.76	3.82	3.84	3.78

6	90:5:5	3.63	3.63	3.64	3.69	3.70	3.67	3.67	3.65
7	95:0:15	3.48	3.42	3.46	3.43	3.52	3.46	3.43	3.45
8	95:15:0	3.64	3.70	3.65	3.65	3.65	3.63	3.66	3.64
9	85:5:10	3.44	3.43	3.55	3.42	3.48	3.48	3.44	3.46
10	85:10:5	3.44	3.43	3.55	3.42	3.48	3.45	3.45	3.43
11	80:0:20	2.97	2.89	2.98	2.98	2.93	2.99	3.06	2.98
12	80:20:0	3.20	3.13	3.19	3.15	3.15	2.99	3.16	3.19
13	80:5:15	2.97	2.91	2.94	3.05	2.95	2.96	2.98	3.07
14	80:15:5	2.99	2.87	2.96	2.98	2.91	2.89	2.89	2.95
15	80:10:10	3.00	2.99	3.03	3.01	3.01	2.98	2.98	2.97
16	70:0:30	2.47	2.48	2.51	2.53	2.55	2.43	2.39	2.50

*Wht:cas:cow-Wheat:cassava:cowpea

Appendix VI: Baking losses of composite bread, Morogoro, Tanzania

Formulations	Composition Wht:cas:cow*	Unsoaked cassava bread Kiroba (g)	Mzuri.Kwao (g)	Mumba (g)	Kigoma (g)	Soaked cassava breads Kiroba (g)	Mzuri.Kwao (g)	Mumba (g)	Kigoma (g)
1	100:0:0	880	880	890	885	880	880	875	885
2	95:5:0	850	860	870	860	865	870	860	860
3	95:0:5	860	870	870	860	870	865	870	860
4	90:0:10	820	825	840	825	820	820	830	825
5	90:10:0	820	830	825	825	820	825	825	820
6	90:5:5	820	825	820	830	840	830	825	825
7	95:0:15	790	780	790	785	800	790	785	790
8	95:15:0	790	800	785	785	785	780	790	790
9	85:5:10	780	785	780	770	790	785	785	790
10	85:10:5	780	785	780	770	780	785	790	790
11	80:0:20	680	660	680	680	670	680	700	680
12	80:20:0	690	680	690	680	680	650	680	680
13	80:5:15	680	670	670	700	670	680	680	700
14	80:15:5	680	660	670	680	670	660	660	670

15	80:10:10	685	680	690	690	690	685	685	680
16	70:0:30	580	570	590	590	600	560	565	580

*Wht:cas:cow-Wheat:cassava:cowpea

Appendix VII: Loaf volume and bread specific volume, Maputo, Mozambique

Formulations	Compositions Wht:cas:cow*	Nhambatsana		Chinhembué		Kusse		Tchicela ni Tchai	
		Loaf volume (ml)	Specific volume (ml/g)	Loaf volume (ml)	Specific volume (ml/g)	Loaf volume (ml)	Specific volume (ml/g)	Loaf volume (ml)	Specific volume (ml/g)
1	100:0:0	610.00	2.26	600.00	2.22	620.00	2.30	620.00	2.29
2	95:5:0	600.00	2.26	590.00	2.23	570.00	2.13	600.00	2.24
3	95:0:5	590.00	2.16	590.00	2.16	570.00	2.09	580.00	2.13
4	90:0:10	570.00	2.08	550.00	2.07	560.00	2.04	590.00	2.15
5	90:10:0	560.00	2.07	550.00	2.04	570.00	2.10	570.00	2.10

6	90:5:5	540.00	1.97	530.00	1.93	570.00	2.09	550.00	2.00
7	95:0:15	520.00	1.89	530.00	1.93	530.00	1.93	530.00	1.99
8	95:15:0	530.00	1.96	540.00	2.01	530.00	2.00	550.00	2.07
9	85:5:10	530.00	1.91	520.00	1.87	530.00	1.89	525.00	1.88
10	85:10:5	520.00	1.87	530.00	1.89	535.00	1.92	520.00	1.87
11	80:0:20	500.00	1.79	510.00	1.83	500.00	1.80	490.00	1.76
12	80:20:0	520.00	1.92	510.00	1.88	490.00	1.85	520.00	1.93
13	80:5:15	510.00	1.83	520.00	1.87	500.00	1.87	500.00	1.90
14	80:15:5	490.00	1.76	520.00	1.89	500.00	1.79	500.00	1.80
15	80:10:10	500.00	1.80	510.00	1.83	530.00	1.90	520.00	1.87
16	70:0:30	460.00	1.63	450.00	1.58	460.00	1.64	420.00	6.00

*Wht:cas:cow-Wheat:cassava:cowpea