EFFECT OF GRATING, CHIPPING, DRY FERMENTATION AND SUN DRYING ON CYANIDE LEVEL OF CASSAVA IN TONGWE VILLAGE

BY

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ABSTRACT

This study was conducted to evaluate effectiveness in cyanide reduction by four different methods of processing cassava roots, two traditional (dry fermentation and direct sun drying) and two improved methods (grating and chipping) and also assess losses due to cassava processing in Tongwe village (Muheza District). Presence of mycotoxin-producing organisms in fermented cassava flour was examined. Cyanogens were determined using the AOAC alkaline titration method. The microbial growth was done on plate using Sabouraud's Dextrose Agar (SDA). The cyanide level, in the processed cassava differed significantly ($p<0.05$). Improved methods were more effective than traditional. The mean cyanide was; 6.79, 7.96, 8.96 and 9.90 mg HCN/kg DWB for grating, chipping, dry fermentation and direct sun drying, respectively. Identification of mould revealed the absence of mycotoxin producing organisms and therefore ruled out the possibility of presence of mycotoxins in the dry fermented cassava flours collected from 60 households in Tongwe and 10 samples prepared in Tongwe cassava processing unit. Losses due to processing in all four methods were determined by calculating the difference between peeled fresh cassava weight and the weight of flour produced after processing. Results showed significant differences ($p<0.05$) between the traditional and improved methods studied. The mean percentage losses were; 67.28, 69.73, 51.83 and 54.14 for grating, chipping, dry fermentation and direct sun drying, respectively. Sensory evaluation done at SUA and Tongwe showed significant differences ($p<0.05$) in preferences between the stiff porridge prepared using flour from all four methods of processing cassava, the most preferred product being *ugali* from chipped cassava flour. This experiment has indicated that improved methods are more effective in cyanide reduction than traditional ones. However, traditional methods were more economical in processing losses and that there were no mycotoxin-producing organisms in fermented cassava flour. Both methods produce acceptable products worth encouraging if losses are minimized.

DECLARATION

I MWANAIDI ALLI KHATIB do hereby declare to the Senate of Sokoine University of Agriculture that this is my own original work and has not been submitted for any degree in any other university.

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13th Nov 2009
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The above declaration confirmed

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DEDICATION

This work is dedicated to my beloved son ABDULWAKIL, who passed away on 4th June 2008, while I was away doing my studies. May "Allah" rest his soul in "Jannah". Baby I will always remember you as a great man.

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LIST OF ABBREVIATIONS

ACS	-	American Cancer Society
ANOVA	-	Analysis of Variance
AOAC	-	Association of Official Analytical Chemists
ATSDR	-	Agency for Toxic Substances and Disease Registry
CIAT	-	International Centre for Tropical Agriculture
CN	-	Cyanide
DGSI	-	Direction Générale des Stratégies Industrielles
FAO	-	Food and Agriculture Organization
HCN	-	Hydrocyanic acid
H_2O	-	Water
IFAD	-	International Fund for Agriculture Development
IITA	-	International Institute of Tropical Agriculture
kg	-	Kilogramme
mg	-	Milligramme
mt/ha	-	Metric tonnes per hectare
NaOH	-	Sodium hydroxide
SUA	-	Sokoine University of Agriculture

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Cassava is one of the most important staple food crops grown in tropical Africa. It plays a major role in efforts to alleviate the African food crisis because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions and suitability to present farming and food systems in Africa (Hahn and Keyser 1985, Hahn *et al.*, 1987).

The principal parts of the mature cassava plant expressed as a percentage of the whole plant are leaves 6 percent; stem 44 percent and storage roots 50 percent. The roots and leaves of the cassava plant are the two nutritionally valuable parts, which offer potential as a feed source. The cassava storage root is essentially a carbohydrate source. Its composition shows 60-65 percent moisture, 20-31 percent carbohydrate, 0.2-0.6 percent ether extracts, 1-2 percent crude protein, and comparatively low vitamins and minerals. However, the roots are rich in calcium and vitamin C and contain a nutritionally significant quantity of thiamine, riboflavin, and nicotinic acid. Of its carbohydrate, 64-72 percent is made up of starch (Tewe, 2004). The starch content increases with the growth of the storage roots and reaches a maximum between the 8^{th} and 12^{th} month after planting.

Thereafter, the starch decreases and the fibre content increases. Cassava starch contains 20 percent amylose and 70 percent amylopectin. Cassava roots also contain sucrose, maltose, glucose, and fructose in limited levels. The raw starch of the cassava root has a digestibility of 48.3 percent while cooked starch has a digestibility of 77.9 percent (Tewe, 2004).

Traditionally, cassava roots are processed by various methods into numerous products and utilized in various ways according to local customs and preferences. Fresh cassava roots cannot be stored for long time because they rot within 3-4 days of harvest. They are bulky with about 70% moisture content, and therefore transportation of the roots to urban markets is difficult and expensive (Hahn, 1989). Some cassava roots contain large amounts of cyanohydrin that emanates cyanide, a toxic compound for human health, and gives the root a bitter taste. Cultivars are accordingly classified as sweet or bitter depending on their cyanide content. Bitter varieties are especially fitted for industrial and feed purposes, because of their higher starch content, while sweet varieties are generally preferred to be consumed as food (FAO, 2000).

Fresh cassava has low value per unit weight; processing adds value and therefore extends the market especially to urban consumers (Nweke *et al.*, 1998). The roots and leaves contain varying amounts of cyanide which is toxic to humans and animals. The raw cassava roots and uncooked leaves are not palatable. Unlike sweet cassava, bitter cassava is not safe for human consumption unless properly treated (FAO, 2000). Therefore, cassava must be processed into various forms in order to increase the shelf life of the products, facilitate transportation and marketing, reduce cyanide content and improve palatability (Hahn, 1989).

Ingested cyanide is metabolised in the human body by its reaction with sulphanes to produce thiocyanates. The sulphur for the sulphanes comes from methionine and cystine, two essential amino-acids. Ironically, the detoxification of cyanides to produce thiocyanates is not without cost to the body physiology (Onwueme, 1994). Not only is it a drain on sulphur-containing amino acids, but high amounts of thiocyanate are known to inhibit the accumulation of iodine in the thyroid gland, resulting eventually in iodine deficiency, endemic goitre, endemic cretinism, and mental retardation. Thus, the danger of high cyanide in cassava is not only in the risk of sudden death when lethal doses are eaten, but also in the more insidious risk of endemic diseases resulting from long term ingestion of sub lethal doses (Onwueme, 1994).

1.2 Problem Statement and Justification

Cassava is the world fourth most important staple after rice, wheat and maize and is an important component in the diet of one billion people in the world. In Tanzania, peeled roots are usually sun dried for one or two weeks and subsequently processed into storable product called "makopa," "kivunde," or "knonowole." Other methods use fermentation to enhance mould growth in products such as "nyange" and "bada" (FAO, 2000).

Apparently, fermentation microorganisms attack the roots during prolonged soaking, making them more permeable. This permits the glucosides, which are water soluble, to leach out from the roots into water. The enzyme linamarase may also directly hydrolyse the glucosides during prolonged soaking. However, prolonged soaking results into an acid solution, which makes further breakdown of cyanohydrins difficult. In any case, no matter how carefully cassava has been processed, traces of cyanides invariably remain in the consumed product (Onwueme, 1994).

Microorganisms can grow in cyanide-containing substrates due to their anaerobic metabolism, their alternative metabolism regarding the respiratory chain and their capacity to detoxify cyanide by splitting the CN^- radical into carbon and nitrogen (Mattos and Cereda, 1996).

Inadequate or slow drying, exposure to high humidity and rewetting during storage will make products such as cassava or cassava chips and flours susceptible to fungal contamination (Bainbridge *et al.*, 1996). In parts of Africa where water is scarce, the roots are covered with leaves or damp cloth, allowing moulds and yests to develop quickly. The mould-covered cassava is then allowed to dry in the sun (Egglestone *et al.*, 1992).

Traditional tools used in processing cassava include: millstone, grinding stone, pestle and mortar. These tools have low productivities and low hygienic conditions these problems lead to the designing and construction of machines that can grate the cassava of high quality in a short period and reduce human drudgery. Some of the machines include: roller crushing mill, hammer mill, bar mill, grater, etc, all having one problem or the other (Ndaliman, 2006). Grating breaks down the cassava so that the cyanide can easily be drawn off (Alyanak, 1997).

Traditional cassava processing methods need to be investigated for labour intensiveness, efficiency, effectiveness of detoxification, acceptability of the final product (taste), and preservation quality of the final products (Akoroda and Teri, 1999). Many processing methods practiced in Tanzania are not effective in reducing cyanogens in roots from bitter cassava varieties with high initial glucoside levels (Mlingi, 1995).

Since literature suggests that there is residual cyanide that remains after processing, research is important to compare the effectiveness of cyanide reduction among different methods. It is also important to investigate and evaluate the safety of product of fermentation by analyzing presence of mycotoxin-producing organisms so as to obtained data which will help to improve traditional processing methods and obtain safe cassava meal that will not threaten the health of consumers of such cassava products.

1.3 Research Objectives

1.3.1 General objective

The general objective was to compare the effectiveness of traditional methods of processing (direct sun drying and dry fermentation) and improved methods (grating and chipping) in detoxification of cassava and assesses the losses encountered during household cassava processing

1.3.2 Specific objectives

i. To quantitatively analyse residual cyanide in cassava flour.

ii. To assess acceptability of stiff porridge through sensory evaluation.

iii. To assess quantitative losses due to processing of cassava in (Bagamoyo) Tongwe village.

iv. Isolate and identify mycotoxin producing organisms in fermented cassava flour

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERVIEW

2.1.1 Scientific classification of cassava

Cassava belongs to the Kingdom: Plantae, Division: Magnoliophyta, Class: Magnoliopsida, Order: Malpighiales, Family: Euphorbiaceae, Subfamily: Crotonoideae, Tribe: Manihoteae, Genus: *Manihot*, Species: *M. esculenta* (Anon, 2006).

2.1.2 Origin of cassava

Cassava (*Manihot esculenta*) is a native of Brazil and during the 16^{th} and 17^{th} centuries it was dispersed widely by the Portuguese in tropical and subtropical areas of Africa, Asia and the Carribean (FAO, 2001). It has been originating from the Amazon basin, where it has been cultivated for more than 5000 years (Vessia, 2008). It soon became a staple food in many places because of its tolerance to drought, poor soil conditions and generally difficult crop environments (FAO, 2001).

2.1.3 Cassava plant characteristics

Cassava is a shrub with an average height of one metre, and has a palmate leaf formation. It belongs to the family of rubber plants (Euphorbiaceae) with white latex flowing out of its wounded stem and leaf stalk. The stem is the planting material from which grows the roots and shoots (Babaleye, 1996). Cassava is a rain fed crop grown mainly in humid and sub humid regions (Madeley, 1998), it produces bulky storage roots with a heavy concentration of carbohydrates, about 80 percent. The shoots grow into leaves that constitute a good vegetable rich in proteins, vitamins and minerals (Babaleye, 1996).

2.1.4 Cassava as staple and food security crop

Cassava is a staple food for people in Angola, Benin, the Democratic Republic of Congo (DRC), Ghana, Malawi, Mozambique, Uganda and Tanzania to mention just a few. It is equally becoming a major food crop in countries of the Sahel: Chad, Burkina Faso, Mali, Niger, and Senegal (Babaleye, 2005). Unpredictable weather conditions and high cost of farm inputs have forced many African governments to earmark cassava as the most suitable alternative food crop (Ntonga, 2003). It supplies daily calories for more than 200 million people in sub-Saharan Africa, and Nigeria is the world leading producer of cassava with more than 34 million tonnes (Babaleye, 2005).

Cassava is useful in bridging seasonal food gaps, in preventing or alleviating famine and in cushioning shortfalls of per capita food production, where environmental and per capita resource conditions are deteriorating (Prudencio and AlHassan, 1994). It can be grown in poor soils and survives erratic rains and drought conditions, which other crops fail (Madeley, 1998). Cassava thus plays an important role in ensuring and stabilizing food security in Africa (Prudencio and AlHassan, 1994).

Cassava gives a carbohydrate production, which is about 40% higher than rice and 25% more than maize, with the result that cassava is the cheapest source of calories for both human nutrition and animal feeding (Tonukari, 2004). Cassava roots can be stored in the ground as food reserve for up to one year, hence saying "Where there is cassava there is no hunger" (Madeley, 1998).

Cassava can grow and produce dependable yields in places where cereals and other crops will not grow or produce well. It can tolerate drought and can be grown on soils with low nutrient capacity, but responds well to irrigation or higher rainfall conditions. and to use of fertilizers (FAO, 2001). It is drought tolerant and serves as a food with many advantages over crops like maize, rice and wheat which often fail because of Africa's erratic rainfall patterns, lack of fertiliser and poor soils.

2.2 Composition of the Cassava Roots

The root consists of the peel and the flesh. The peel comprises 10-20% of the roots. Of this, the cork layer represents 0.5-2.0% of the total root weight. The edible fleshy portion constitutes 80-90% of the roots. The roots flesh is composed of about 62% water, 35% carbohydrate, 0.5-1.5% protein, 0.3% fat, 1-2% fibre, and 1% mineral matter,. Most of the carbohydrate fraction is starch, which makes up 20-25% of the roots flesh. Among the minerals in the roots, phosphorus and iron predominate. There is small amount of calcium. It is relatively rich in vitamin C (35mg per 100g fresh weight), and contains traces of niacin and vitamins A, B_1, and B_2, but the amount of thiamine and riboflavin are negligible (Onwueme, 1994).

Cassava root is a poor source of protein as shown in (Table1). The quality of cassava root protein is however, fairly good as far as the proportion of essential amino acids as a percentage of total nitrogen is concerned. Methionine, cysteine and cystine are however limiting amino acids in the root. Only about 60 percent of the total nitrogen is derived from amino acids and about one percent of it is in the form of nitrates, nitrites and hydrocyanic acid. The remaining 38-40 percent of the total nitrogen remains unidentified. Peeling results in the loss of part of the valuable protein content of the root because the peel contains more protein than is found in the root flesh. The amino acid level of cassava roots show higher levels of lysine and tryptophan in its true protein fraction (Tewe, 2004).

Table 1: Nutrients in cassava compared with other food products

	Calories per 100g	Protein	Fat	Carbohydrate	Ash	Moisture	Fibre
				Percent			
Cassava roots	127	0.8-1.0	0.2-0.5	32	0.3-0.5	65	0.8
Cassava flour	307	0.5-0.7	0.2	85	0.3	15	0.5
Potatoes	89	2.1	0.1	20	1.0	77	0.7
Potato flour	331	-	0.3	82	0.3	15	0.4
Husked rice	347	8.0	2.5	73	1.5	15	0.7-1.0

Source: FAO (2000)

Raw cassava roots are an excellent source of calories compared to potatoes and also it has more carbohydrate compared to potatoes and husked rice they have less protein and moisture compared to potatoes.

2.3 The Toxic Compound of Cassava (Cyanogenic Glucosides)

Cassava is a widely grown root crop, which accumulates two cyanogenic glucosides, linamarin and lotaustralin. Linamarin accounts for more than 80% of the cassava cyanogenic glucosides. It is a ß-glucoside of acetone cyanohydrin and ethyl-methyl-ketone-cyanohydrin. Linamarin ß-linkage can only be broken under high pressure, high temperature and use of mineral acids, while its enzymatic break occurs easily. Linamarase, an endogenous cassava enzyme, can break this ß-linkage. Linamarin is present in all parts of the cassava plant, being more concentrated in the roots and leaves. If the enzyme and substrate join, a good detoxification can occur (Mattos and Cereda, 1996). Cyanogenic glucosides belong to the group of secondary metabolites contained in the cell vacuoles, which are potentially toxic (Vessia, 2008).

The presence of cyanide in cassava has caused a global scare as to the safety of cassava and its products for human and animal consumption. The concentration of the glycosides varies considerably between varieties and also with climatic and cultural conditions. The normal range of cyanogenic glucosides content in fresh roots is from 15-400 ppm calculated as mg HCN/kg fresh weight but occasionally varieties with very low HCN content of 10 mg/kg or very high HCN content of 2000 mg/kg have been reported (Tewe, 2004).

HCN is a colourless, volatile and extremely poisonous compound whose vapour has a bitter almond odour, it melts at -14°C and boils at 26°C. It is miscible with water or ethanol and is soluble in ether. Its water solution is a weak acid commonly known as hydrocyanic acid or prussic acid and its salt is called cyanides (The Columbia Encyclopedia, 2008). Cassava is often classified as "bitter or sweet" according to the amount of cyanide present. However, several studies have shown that bitterness or sweetness could not be exactly correlated with the level of cyanogenic glucosides (Tewe, 2004).

The breakdown of linamarin leads to formation of acetone cyanohydrin and glucose (Fig. 1). At pH above 5, the acetone cyanohydrin will spontaneously break down into acetone and HCN. This breakdown may also be catalysed by the enzyme hydroxynitrile lyase (HNL) which is also present in cassava. Once HCN is produced, it will dissipate in the air (since its boiling temperature is 25.7°C). In damaged plant tissues, which include processed roots and leaves, it is possible to find non-hydrolysed cyanogenic glucosides, cyanohydrins and traces of HCN. The term cyanogen refers to any of these three compounds. (Bokanga, 1996).

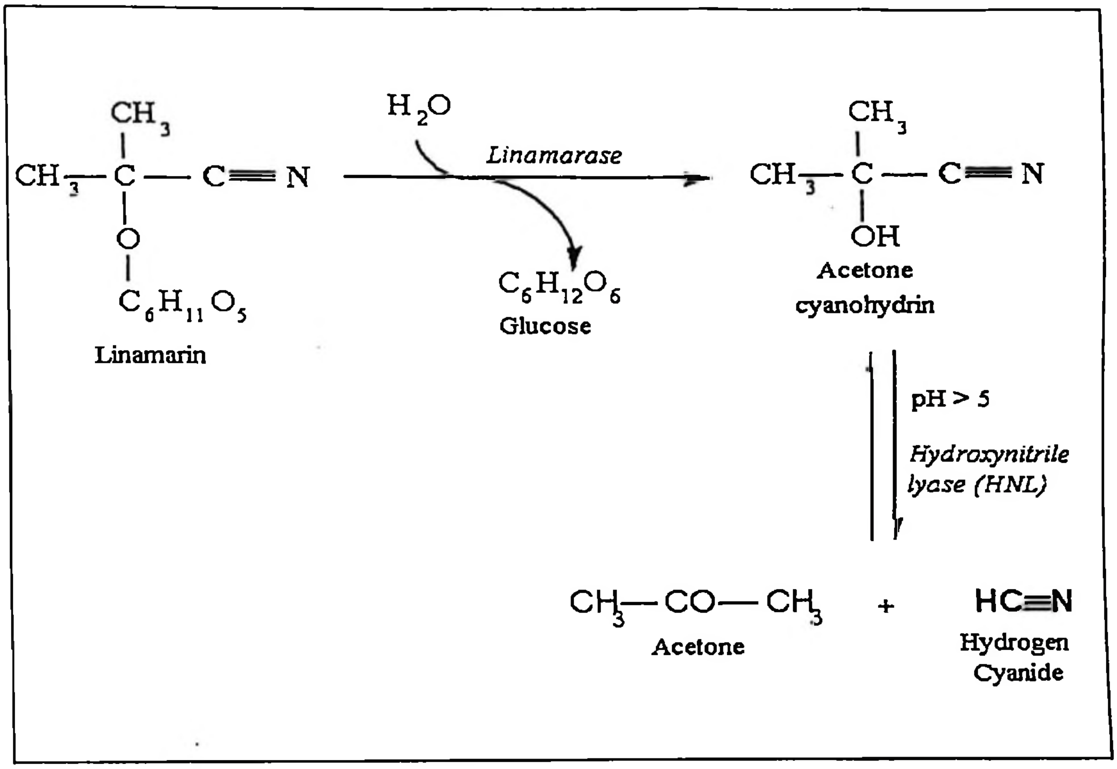

Figure 1: Enzymatic hydrolysis of linamarin (Bokanga, 1996).

Earlier classifications of cassava safety limits provided by Bolhuis (1954) cited by (Tewe, 2004) indicate:

i) Innocuous: less than 50 mg HCN/kg/fresh peeled storage root;

ii) Moderately poisonous: 50-100 mg HCN/kg fresh peeled storage root;

iii) Dangerously poisonous: over 100 mg HCN/kg fresh peeled storage root

Some of the signs of cyanide poisoning are headache, dizziness, agitation, confusion, coma, and convulsions (ACS, 2007).

All the cassava plant species have been known to contain cyanide (Mattos and Cereda, 1996). According to Maduagwu, who was a post-doctoral fellow at the International Institute of Tropical Agriculture (IITA) in Nigeria as quoted by Ntonga (2003), the toxicity of cassava attributable to its cyanide content has been recognized as a serious health hazard in the tropics for many years. The author says: "In 1966, two lethal cases of cyanide poisoning following ingestion of sweet cassava roots were reported on the East African island of Pemba and three years later, a similar case was reported of a three-and-half year old Indian child who died after eating tapioca (another name for cassava)."

The World Health Organization (WHO) is currently investigating 60 cases of upper motor neuron disease with paralysis of the limbs known as "Konzo" in Pemba, Tanzania, which occurred in September 2003 and have been attributed to cassava (Ntonga, 2003).

2.4 Post harvest Deterioration of Cassava

2.4.1 Physiological or primary deterioration

Physiological deterioration is the first to appear and is caused by rapid post harvest accumulation of phenols, especially scopoletin, which, in the presence of oxygen, forms blue, black, and brown pigments. Scopoletin can be detected by exposing roots to ultraviolet light (CIAT, 2001a). Chemical and spectroscopic examinations revealed the accumulation of hydrxycoumarins (esculin, esculetin, scopolin and scopoletin) campounds derived from the phenylpropanoid pathway, during the time course of post-harvest deterioration (Buschman *et al.*, 2000). Deterioration starts 24 to 48 h after harvest at those places where mechanical damage has occurred. Symptoms include a white or coffee-coloured ring as a result of desiccation at the periphery of the pulp and some blue-black streaks, especially near the xylem (CIAT, 2001a).

2.4.2 Microbial or secondary deterioration

Microbial or secondary deterioration appears, especially in areas with physical damage, 5 to 7 days after harvest, and is caused by fungi or bacteria. Deterioration is hastened in environments with high relative humidity and temperatures. Symptoms include vascular streaking and later soft rot, with fermentation and maceration of tissues (CIAT, 2001a). Metabolism of scopoletin to an insoluble coloured product is by means of peroxidase. This product is believed to be the cause of the discolouration of the vascular tissue during storage (Buschman *et al.*, 2000). An oxidative burst occurs within 15 minutes of the root being injured, that is followed by the altered regulation of genes, notably for catalase and peroxidase, related to modulation of reactive oxygen species, and the accumulation of secondary metabolite, some of which show antioxidant properties (Reilly *et al.*, 2003). Etiological studies have isolated fungi of the genera *Penicillium, Aspergillus, Rhizopus*, and *Fusarium*, and several bacteria, including species of *Bacillus, Pseudomonas*, and *Corynebacterium* (CIAT, 2001a).

2.4.3 Mycotoxin contamination

Mycotoxins are metabolites produced by some strains of certain fungi that cause illness, mycotoxicosis, or death when ingested by animal and human. Contamination of foods and feeds by mycotoxins depends largely on the presence of environmental conditions which, lead to mould growth and hence toxin formation. Probably no food or feed commodity can be regarded as immune to the presence of mycotoxins, since toxin contamination can occur in the field or during harvesting, drying, processing, storage and transportation of a particular commodity (Bainbridge *et al.*, 1996).

After screening 30 samples, Essers (1995) revealed that there were no mycotoxins detected. According to Muzanila *et al.* (1999) there was no mycotoxin detected in Tanzania cassava samples prepared by solid state fermentation.

According to Bainbridge *et al.* (1996), the potential of cassava and processed cassava products to support the growth of mycotoxigenic fungi with concomitant toxin production has not been extensively studied. Although many mycotoxin analyses have been developed, very few have been validated with cassava or root crops. The products of mould fermented cassava flour have been reported to be safe (Thambiraj, 1989).

2.5 Cassava Processing

Processing is carried out to:

i) Reduce water content in the roots to convert them into products that are more stable, easier to transport, and more marketable.
ii) Eliminate or reduce cyanogenic glucoside contents.
iii) Improve the flavour of cassava products.
iv) Create an opportunity for farm surpluses to receive aggregate value and thus enter alternative markets (CIAT, 2001b).

The processing methods involve combination of activities, which are performed in stages. Such activities are peeling, crushing, milling, slicing or grating; water expressing by pressing, decanting, sun or smoke-drying, or frying, fermenting by soaking with water, heaping, stacking or sedimentation, sieving and cooking and boiling or steaming (Nweke *et al.*, 1998).

2.5.1 Peeling

The first step in processing cassava roots is often to remove the peel. This results in a great reduction of the cyanogenic potential of the raw material because the peel represents about 15 percent of the weight of the root, and its cyanogen content is usually 5 to 10 times greater than that of the root parenchyma. However, the peel also contains large amounts of the enzyme linamarase which is important in the detoxification of cassava during processing (Bokanga, 1996).

Peeling is done with a sharp knife. Peeling during dry season is more difficult because the skin adheres more strongly to the dry flesh of the roots and loss of dry matter is high (FAO, 1997). Little reliable information is available on loss figures. In some document these figures seem to be only gross estimate and frequently the terms waste and losses used without clear distinction (FAO, 1995). FAO data for 1985 estimated that post harvest loss for all root crops in Ghana are of the order of 15 to 30 percent and post-harvest loss of cassava in Cote de'Ivoire is 27 percent (FAO, 1995).

2.5.2 Soaking

It is a primary step in processing of roots, since it removes bitterness, improves flavours and softens the roots for subsequent grinding or pounding. Of these factors removal of bitterness is regarded as the most important. The process is affected by prevailing weather conditions; longer soaking being required in the cold season 7 to 10 days compared to the warm season 2 to 3 days (FAO, 1997).

2.5.3 Drying

Traditionally, cassava is dried by spreading whole, sliced or pounded roots in the sun although during rainy season or periods of cold weather, the cassava may be dried over a fire. Sun drying in dry season usually takes 2 to 3 days but in rainy season the drying period may extend to over a week (FAO, 1997). Drying is the simplest method of processing cassava. It reduces moisture, volume and cyanide content of roots, thereby prolonging product shelf life. This processing is practiced primarily in areas with fewer water supplies (Hahn, 1989).

Sun or smoke-drying of peeled fresh cassava roots is not effective in eliminating cyanogens if present in the roots (Hahn, 1989). Total cyanide content of cassava chips could be decreased by only 10-30 percent through fast air drying. Slow sun-drying, however, produces greater loss of cyanide. Sun-dying the peeled cut pieces of roots gave HCN concentration lower than 10 mg/100g and loss was more effective than oven drying (Mahungu *et al.,* 1987). Drying may be in the sun or over a fire. The former is more common because it is simple and does not require fuelwood (Hahn, 1989).

2.5.4 Grinding

Traditionally, in rural areas, cassava is pounded using a pestle and a mortar to produce flour (FAO, 1997).

2.5.5 Cassava grating

The cassava root is peeled, washed and grated. It is then placed in a container and covered for three hours. A funnel is made from papyrus, and the pulp is pushed through it with a stick, squeezing out the water with the toxins until what is left is dry. The rest is then put on an iron sheet in the sun (Alyanak, 1997). Fresh cassava roots are grated, pressed or squeezed to remove excess water and then dried (Guzman, 2004). The process takes a day, not a week like it used to (Alyanak, 1997).

2.5.6 Cassava fermentation

Fermented foods as defined by Campbell-Platt (1987) cited by Sahlin (1999) are those foods which have been subjected to the action of micro-organisms or enzymes so that desirable biochemical changes cause significant modification to the food. The fermentation of the cassava roots is a lactic fermentation (pH 3.8) with *Lactobacillus* as dominant microflora whereas that of the cassava leaves is an alkaline fermentation (pH 8.5) where *Bacillus* constitutes the main microflora. The hydrolysis of cyanogenic glucosides takes place as well in acid medium during the cassava roots fermentation as in basic medium with the cassava leaves fermentation. The cyanide content decreases during the fermentation of cassava roots and leaves by more than 70% through the activities of the bacterial produced linamarase, allowing the hydrolysis of cyanogenic glucosides. Certain lactic bacteria present in the environment of fermentation are resistant to the strong cyanide concentrations of between 200 and 800 ppm (Kobawila *et al.*, 2005).

Fermentation consists of two distinct methods: aerobic and anaerobic fermentation. For aerobic fermentation, the peeled and sliced cassava roots are first surface-dried for 1-2 hours and then heaped together, covered with straw or leaves and left to ferment in air for 3-4 days until the pieces become mouldy. The fermented mouldy pieces are sun-dried after the mould has been scraped off. The processed and dried pieces (called "makopa" in Uganda) are then milled into flour, which is prepared into a "fufu" called "kowan" in Uganda. The growth of mould on the root pieces increases the protein content of the final products three to eight times (Amey, 1987).

In anaerobic fermentation, grated cassava for processing into "gari" is placed in sacks and pressed with stones or a jack between wooden platforms. Whole roots or pieces of peeled roots for processing into "fufu" are placed in water for 3-5 days. During the first stage of *gari* production, the bacteria *Corynebacterium manihot* attacks the starch of the roots, leading to the production of various organic acids (such as lactic and formic acids) and the lowering of substrate pH. In the second stage, the acidic condition stimulates the growth of a mould, *Geotrichum candida*, which proliferates rapidly, causing further acidification and production of a series of aldehydes and esters that are responsible for the taste and aroma of *gari*. The optimum temperature for the fermentation for *gari* processing is 35°C, increasing up to 45°C (Odunfa, 1985).

2.5.7 Storage of processed products

Processing, particularly drying and roasting, increases shelf life of cassava products. Good storage depends on the moisture content of the products and temperature and relative humidity of the storage environment. The moisture content of *gari* for safe storage is below 12.7%. When temperature and relative humidity are above 27°C and 70% respectively, *gari* goes bad (Igbeka, 1987). The type of bag used for packing also affects shelf life depending on the ability of the material to maintain safe product moisture levels.

Jute and bags are recommended in dry cool environments because they allow good ventilation (Igbeka, 1987). When *gari*, dried pulp and flour are well dried and properly packed, they can be stored without loss of quality for over one year. Dried cassava balls ("kumkum") can be stored for up to 2 years (Numfor and Ay, 1987).

2.6 Uses of Cassava

Cassava is used in a number of ways e.g. human food, animal feed, medicine, industrial starch and other uses.

2.6.1 Human food

Cassava is the basic staple crop for 500 million people in tropical and sub-tropical parts of the world and one of the most reliable and cheapest sources of food (IFAD and FAO, 2000). World consumption of cassava for food (fresh or processed) is concentrated in the developing world. In Africa, about 70% of cassava production is used as food (Cortés *et al.*, 2002). In the early 2000s 95% of the total cassava production after accounting for waste was used as food in Africa. By contrast 55% of total production in Asia and 40% in South America are used as food (Nweke, 2004). The most popular processed products are commonly known *as gari*, *lafun*, *foufou*, *attiéké* and *chickwangue*. *Gari*, a dry granular meal made from moist and fermented cassava, is most commonly used in West Africa. Other forms of processed cassava consumption include a sun-dried cassava known as *lafun* in southwest Nigeria and sticky or heavy soups made from fermented cassava known as *foufou*. In other parts of Africa, cassava is commonly made into flour from dried roots or chunks of roots, and consumed as flour product commonly named *attiéké* and *chickwangue* (Cortés *et al.*, 2002).

Cassava is grown for its enlarged starch-filled roots, which contain nearly the maximum theoretical concentration of starch on a dry weight basis among food crops. Fresh roots contain about 30% starch and very little protein (O'hair, 1995).

In Africa, cassava provides a basic daily source of dietary energy. Roots are processed into a wide variety of granules, pastes, flours, etc., or consumed freshly boiled or raw. In most of the cassava-growing countries in Africa, the leaves are also consumed as a green vegetable, which provides protein and vitamins A and B (IITA, 2007).

2.6.2 Animal feed

Of a total production of 87 million tonnes annually in Africa, only 6 percent is used in livestock production mainly in traditional systems. By contrast, in Latin America, 32.4 percent of its cassava is used for livestock feeding while in Asia, over 40 percent of its products is exported in the form of chips and pellets for the European Union livestock industry with another 2.9 percent used for domestic livestock production (IFAD and FAO, 2000).

2.6.3 Medicinal Uses

Cassava has had many folk medicine uses in tropical and subtropical countries, where it has been a staple food for millions of people. Leaves and roots have been a folk remedy for tumors and cancers, which may be due to the B_{17} content, also known as laetrile (Shipard's, 2003).

It has been reported that cassava may have anti-cancer properties. Genes isolated from the plant have already been used to eradicate brain tumours in laboratory rats. The killer-suicide system linamarase/linamarin (lis/lin) uses the plant gene linamarase to convert the cyanogenic glucoside substrate, linamarin, into glucose and cyanide. This mechanism does not preferentially kill toxic metabolite producer cells compared with bystander cells, thus allowing production of sufficient cyanide to cause tumor regression. Glucose and cyanide can diffuse across the membrane (Cortés *et al.*, 2002).

2.7 Effect of Processing Methods on Cyanide Level

2.7.1 Fermentation

The cyanide content in cassava roots falls progressively during fermentation, from 414 to 93 ppm (77.53% reduction). The fermentation is thus a detoxification process. The cyanide content varies very little during the first 24h of fermentation, but decreases drastically from 1158 to 339.6 mg/kg after 48h of fermentation, which corresponds to 70.67% reduction (Kobawila *et al.*, 2005). During fermentation of *gari* and *fufu* acidity increases while cyanide decreases and percentage yield also decreases by 49.9 and 60.3 for *gari* and *fufu*, respectively (Idowu and Akinrele, 1994).

2.7.2 Method of size reduction and drying

Researches indicate that the method of size reduction and particle size control the rate of glucoside degradation, and that the drying rate limits the quantity of glucosidic cyanide eliminated; Drying at 50°C eliminated approximately 50% of the total cyanide from mechanically prepared chips, and 25% from manually prepared chips. Mechanical chipping and drying at 50°C eliminated 65% of the total cyanide from small chips and 47%

from large chips. Mincing of whole roots completely degraded the glucoside, and rasping and mechanical chipping degraded 70-80% and 30% of the initial glucoside, respectively (Jones *et al.*, 2006). Seventeen days of sun-drying of longitudinally split roots only reduced cyanogenic glucosides to 27 to 37%, leaving more than 100 mg/kg HCN (Mlingi *et al.*, 1995).

2.7.3 Boiling

Boiling the peeled roots did not effectively remove HCN. Pounding the boiled roots into "pounded fufu" decreased the HCN concentration by only 10 percent. Therefore, only cultivars containing low cyanide are recommended for this method of preparation (Mahungu *et al.*, 1987).

2.7.4 Storage

During storage there is rapid accumulation of total sugars accompanied by small decline in starch content and although roots get softened during storage it requires a longer cooking time for human consumption. Stored roots have sweet flavour and frequently uneven texture not present in fresh roots (Booth *et al.*, 1976).

2.9 Cassava in the World

According to FAO estimates, 172 million tonnes of cassava were produced worldwide in 2000. Africa accounted for 54%, Asia for 28%, and Latin America and the Caribbean for 19% of the total world production. In 1999 Nigeria produced 33 million tonnes making it the world's largest producer (IITA, 2007). The largest producer of cassava is Brazil, followed by Thailand, Nigeria, Zaire and Indonesia. Production in Africa and Asia continues to increase, while that in Latin America has remained relatively level over the past 30 years. Thailand is the main exporter of cassava with most of it going to Europe (O'hair, 1995).

Global cassava production reached over 160 millions tonnes in 1999, and FAO forecasts that production will rise to nearly 210 million tonnes by 2005. On average, farmers produce about 10 tonnes of cassava per hectare, but yields can reach as high as 40 tonnes/ha. It is estimated that the introduction of high-yielding varieties, improved pest and disease control and better processing methods could increase cassava production in Africa by 150 percent (FAO, 2000). In terms of area harvested, a total of 16.8 million hectares was planted with cassava throughout the world in 2000. About 64% of this was in sub-Saharan Africa. The average yield in 2000 was 10.2 tonnes per hectare, but this varied from 1.8 tonnes per hectare in Sudan to 27.3 tonnes per hectare in Barbados. In Nigeria, the average yield was 10.6 tonnes per hectare (IITA, 2007).

Sub-Saharan Africa is expected to experience the most rapid growth in food demand in root and tubers averaging 2.6 percent per year through 2020 (Scott *et al.*, 2000). This growth will account for nearly 122 million metric tonnes with most of the increase coming largely from cassava, 80 million metric tonnes (66% of the total). Cassava demand is estimated to grow at 2.0% annually for food and 1.6% per year for feed in developing countries, while total cassava production is projected to reach 168 million tonnes by 2020 based on the current production rate (Table 2). However, this amount can be far surpassed in developing countries with the right policies and incentives. Moreover, with the increasing establishment of starch-utilizing industries in developing countries, the production of starch will simply have to increase beyond the projected figures in Table 2. (Scott *et al.*, 2000).

Table 2: Cassava production and use in 1993, and projected to 2020

	Area (million ha)		Yield (mt/ha)		Production (million mt)		Total use (million mt)	
Country/region	1993	2020	1993	2020	1993	2020	1993	2020
Sub-Saharan Africa	11.9	15.9	7.4	10.6	87.8	168.6	87.7	168.1
Latin America	2.7	2.7	11.3	15.6	30.3	41.7	30.3	42.9
Southeast Asia	3.5	3.5	12.1	13.7	42.0	48.2	18.9	24.4
India	0.2	0.2	23.6	28.4	5.8	7.0	5.7	7.3
Other South Asia	0.1	0.1	9.4	13.5	0.8	1.3	0.9	1.4
China	0.3	0.3	15.1	20.2	4.8	6.5	5.1	6.4
Other East Asia	na	na	na	na	na	na	1.8	1.9
Developing	18.8	22.9	9.2	12.0	172.4	274.7	152.0	254.6
Developed	...	...	12.1	14.7	0.4	0.4	20.7	20.5
World	18.8	22.9	9.2	12.0	172.7	275.1	172.7	275.1

Source: Scott *et al.* (2000)

2.10 Cassava in Africa

Cassava was brought to Africa from Brazil by Portuguese slave in 16^{th} century and landed at Elmina on the Ghananian coast (Madeley, 1998). Over 50% of the current global cassava production is grown in Africa. Although the crop is cultivated in 39 countries, stretching through a wide belt from Madagascar in the southeast to Senegal and to Cape Verde in the northwest, nearly 70% of the regions output is harvested in Nigeria, the Congo Democratic Republic and Tanzania. Cassava yield in the region vary from a high 18.5 tonnes per hectare in Cameroon to low 5.3tonnes per hectare in Angola. At the regional level, they averaged 8.2 tonnes per hectare in 1994, little changed from the 7.3 tonnes per hectare in 1984 (FAO, 2000).

Cassava is grown almost exclusively in the arid and semi-arid tropics, where it accounts for approximately 10% of the caloric value of staple crops. Especially in Africa, it is of immense importance (DGSI, 1991). There is also a regular surplus of cassava in most producing countries. Even so, several governments in Africa have taken positive steps to promote cassava production for industrial processing since many of these countries have large capacities for cassava production (Tonukari, 2004).

Continuing strong growth in food demand for cassava reflects the important role that cassava plays in the diets. The growth rate in food demand also stipulates that cassava will maintain its importance in regional diets as Sub-Saharan Africa continues to urbanize and increase its share of processed food products for consumers in the countryside and in the cities (Tonukari, 2004).

2.11 Cassava in Tanzania

Cassava is cultivated and produced in all regions of Tanzania. The main producing areas are: Mwanza, Mtwara, Lindi, Shinyanga, Tanga Ruvuma, Mara, Kigoma, Coast regions and most regions in Zanzibar (Kapinga *et al.*, 2005). Cassava contributed 12% of the average daily dietary intake per person in Tanzania while maize contributed 23% (Nweke *et al.*, 1998). There is strong speculation that cassava was first cultivated in Zanzibar and Mtwara before it gradually spread into hinterland toward the areas around Lake Tanganyika and Lake Victoria (Msabaha *et al.*, 1986).

In Tanzania, the Ministry of Agriculture usually organises crash programmes when the maize crop is threatened by drought. After the drought is over, government curtails these special extension programmes, as a result, there is little continuity in research and extension and cassava farmers are typically forced to rely on farmer to farmer exchange of varieties, especially those varieties that extend the storage life of cassava in the ground (Nweke, 2004). Cassava is mainly a subsistence crop where 84% of its total production is utilized as human food making it second after maize and the remaining 16% is used as animal feed alcohol brewing, starch production and for export (Kilimo Trust, 2007: Kapinga *et al.*, 2005).

Cassava is an important subsistence food crop in Tanzania, especially in the semi-arid areas and is sometimes considered as a famine reserve when cereals fail due to its drought tolerance. Both roots and leaves of cassava are of major nutritional importance in the country. The estimated annual growth of cassava consumption demand for the period from 1980 to 2000 is 3.4 percent, which is similar to the estimate for maize (Kapinga *et al.*, 2005).

In year 2004/05 the annual total production of cassava in Tanzania was 1.85 million metric tonnes on dry weight basis while year 2005/06 it was estimated to be 2 million metric tonnes (Kilimo Trust, 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Source of samples

Cassava samples were prepared and collected from Bagamoyo hamlet in Tongwe village, which is situated about 15 km from Muheza district in Tanga region. Tongwe consists of 700 households from which 42 are in Bagamoyo. Muheza is one of the seven districts of Tanga region in Tanzania. It is bordered to the north by Kenya to the east by the Tanga district and the Indian Ocean, to the south by Pangani district and to the west by the Lushoto and Korogwe districts. According to 2002 Tanzania National Census, the population of Muheza was 279 423. The village is outstanding in cassava production and processing in Tanzania.

3.1.2 Sample collection procedure

A total of 100 samples were obtained, half during the dry season and the other half during wet season. The procedure used was as follows:-

(i) Samples for evaluation of the effectiveness of the methods of processing towards the reduction of cyanide content were obtained by collecting 5 varieties (2 bitter and 3 sweet) of raw cassava from Tongwe. Each sample was divided into 4 parts for grating, chipping, dry fermentation and direct sun drying and the total number for this was 20 samples prepared in dry season and 20 samples in wet season, making the total number of samples to be 40.

(ii) Sixty flour samples from households which were used for consumption were collected from Bagamoyo hamlet Tongwe. These were used for assessment of cyanide and identification of mycotoxin producing organisms.

3.2 Methods

3.2.1 Preparation of sample

3.2.1.1 Peeling

Peeling was done by using a knife. The peeled cassava was then randomly divided into four parts for further preparations.

3.2.1.2 Preparation of direct sun dried cassava flour

Peeled roots were cut into 3 x 3 to 10 x 3-4cm pieces and left to dry in the sun for 5 days during dry season and 7 days at the beginning of the rainy season. Dried roots were ground into flour using hammer mill and sieved using a 1mm sieve.

3.2.1.3 Preparation of dry fermented cassava flour

Peeled roots were cut into 1 to 4 pieces (depending on size) longitudinally and then dried in the sun for 24 hours. It was then covered with dry coconut tree leaves for 2 days to allow growth of microorganisms for fermentation of the cassava. Mould growth was scraped off by using a knife. Fermented roots were sun dried for 2 days during dry season and 4 days at the beginning of the rainy season. Dried roots were grounded into flour by using hammer mill before sieving using a 1mm sieve.

3.2.1.4 Preparation of grated cassava flour

Preparation of grated cassava flour was done by using a grater manufactured by Intermech Engineering Ltd, Morogoro. Peeled roots were washed, crushed into paste by using a grater then put in a Hessian bag and pressed using screw press to remove water. This was then dried in sun for 1 day during dry season and 2 days at the beginning of rainy season. Dried grated cassava was grounded into flour by using hammer mill before sieving using a 1mm sieve.

3.2.1.5 Preparation of flour from chipped cassava

Preparation of chipped cassava flour was done by using chipping machine fabricated by Intermech Engineering Ltd, Morogoro. Chips were made from washed peeled cassava roots, and then dried in the sun for 1 day during dry season and 2 days at the beginning of rainy season. . Dried chips were grounded into flour by using hammer mill before sieving using a 1mm sieve.

3.3 Determination of Hydrocyanic Acid Content in Cassava

Cyanide content of cassava flour was determined by alkaline titration method outlined in AOAC (1995) official method 915.03B. Ten grammes of ground flour sample were placed in kjeldahl tube; ca 200ml of water was added. The digestion system was assembled into a distillation unit for distillation while distillate-receiving tube was dipped into a 20 ml solution of NaOH (0.5g in 20 ml H_2O). The sample was left connected to the distillation unit to autolyse for 2 hours.

After 2h the samples were separately steam-distilled and 150 ml of distillate was collected in 250ml volumetric flask. The volumes were made to 250 ml with distilled water. Eight millilitres of 6N NH_4OH and 2 mlof 5% KI solution were added in 100mL of the distillate and titrated against 0.02N $AgNO_3$ using micro-burette to a faint but permanent turbidity which was recognized against a black background. (1ml of 0.02N $AgNO_3$ = 1.08 mg HCN (Ag equivalent to 2CN).

3.4 Determination of Moisture Content

This was done according to AOAC (1995) Official method 925.10. Five grammes of cassava flour were weighed in a pre-dried crucible and dried at 105^{0}C for 24h. The crucible containing the dried samples was cooled in a desiccator for 20 minutes then weighed. Percentage moisture was calculated using the following formula:-

$$\% \text{ Moisture} = \frac{A - B}{A} \times 100$$

Where:

A = weight of sample before drying (g)

B = weight of dried sample (g)

3.5 Identification of Moulds

Sterile agar was poured in petri plate and allowed to cool. The medium of choice was Sabouraud's Dextrose Agar (SDA). The sample was inoculated in the plate by digging using a sterile surgical blade.

The plates were incubated in dark place at 22°C (room temperature) and 37°C in the incubator. The plates were counted after 7- 4 days of incubation. The colony characteristics (macromaphology) were recorded.

Slides of mould growth for microscopic examination were prepared in the following way. A portion of the growth was picked off with a needle and placed on a microscope slide containing a drop of lactophenol blue and covered with a clean cover slip. Care was taken to exclude air bubbles. The prepared slide was examined under microscope, first using the low power objective, and then using the X40 (high power dry) objective for closer examination of a selected field (Harrigan & McCance, 1976; Andrews, 1992).

3.6 Sensory Evaluation

The stiff porridge made from each sample was assessed for acceptability, first by 25 panellist from Tongwe, then by 25 panellists from Sokoine University of Agriculture. Five points hedonic scale was used for rating the samples. The parameters assessed were appearance, colour, taste, smell and overall acceptability. Rating of parameters was 5 = Like extremely, 4 = Like moderately, 3 = Neither like nor dislike, 2 = Dislike moderately and 1= Dislike extremely.

3.7 Assessment of Quantitative Losses During Processing

This was done by calculating the difference between the weight of fresh raw cassava and the weight of final product obtained from different processing methods i.e. grating, fermentation, chipping and directs sun drying only. Eight kilogram's of each sample was taken and then processed using the above mentioned methods of processing; each method was repeated six times. The weight of flour obtained was recorded. The difference in weight was established and calculated as percentage loss relative to the weight of peeled cassava used in the analysis.

3.8 Statistical Analysis of the Results

Data from household survey were coded, summarised and entered into Statistical Package for Social Sciences (SPSS). Results from laboratory analysis and sensory evaluation were analysed by analysis of variance (ANOVA) using MSTAT-C statistical programme. Mean was separated by Duncan Multiple Range Test.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

This chapter presents and discusses the results and findings of the study, and it consists of five parts. The first part includes opinion on cassava processing gathered from Tongwe through household survey. The second part discusses laboratory analyses results obtained from cassava flour collected from Tongwe household and those prepared from different processing methods to see the effect of the methods on cyanide level. The third part includes the results of sensory evaluation done in Tongwe and SUA. The fourth part is on results of identification of mould in fermented cassava flour. The last part contains the results of the determination of quantitative losses due to cassava processing.

4.2 Household Survey Results

4.2.1 Characteristics of respondents

Table 3 shows the general characteristics of respondents that include gender, age, education level and occupation. The number of male respondents (Table 3) were 33 out of 60 which is 55.5% . Ages of the respondents ranged from 20 to 75 years, with a mean of 44.7 years. The distribution of age among the interviewees was as follows: - those from 20 – 27 were 9 making 15% of interviewees. Between 28 – 35 years were 12 forming 20% and 36 – 43 years were 11 individuals representing 18.3%. Above 43 years were 28 respondents making 46.7% of the interviewees.

Table 3: Characteristics of respondents (n=60)

Variable	Number (n)	Percentage
Respondents by gender		
Male	33	55.5
Female	27	44.5
Respondents by age range (years)		
20 - 27	9	15.0
28 – 35	12	20.0
36 – 43	11	18.3
Above 44	28	46.7
Education level		
No formal education	8	13.3
Primary school education	47	78.3
Secondary school education	2	3.4
Others (carpentry, laboratory technician)	3	5.0
Occupation		
Farmer	59	98.3
House wife	1	1.7

Most respondents, (78.3%), had attended primary school education, while 13.3% had no formal education and 3.4% had completed secondary school education at ordinary level. Only 5% had attended other professional training including carpentry and laboratory technology. Almost all the interviewees were farmers (98.3%).

4.2.2 Cassava varieties cultivated in Tongwe

From the survey in Tongwe households, it was noted that 22 varieties of cassava were being cultivated (Table 4). According to the respondents the most common variety is *Kiroba* followed by *Kibandameno*. Other varieties were only available in one household and they were about to disappear because of introduction of *Kiroba* since *Kiroba* was high yielding. However, some farmers reported that *Kiroba* changed to bitter taste in their field after maturity and so it had to be harvested as soon as it was ready if it was to be consumed as boiled cassava.

Table 4: Common cassava varieties in Tongwe and their status

	Cassava variety	Category	Source	Status	Reason for abandonment
1.	*Kiroba*	Sweet/bitter	Introduced	Present	
2.	*Kibanda meno*	Sweet	Indigenous	Present	
3.	*Mamosi*	Sweet	Indigenous	Present	
4.	*Sina wangu*	Bitter	Indigenous	Present	
5.	*Mahiza*	Sweet	Indigenous	Abandoned	Rotting
6.	*Kaguru kaninga*	Sweet	Indigenous	Abandoned	*Kiroba*
7.	*Kasunga*	Sweet	Indigenous	Present	
8.	*Pusuu*	Sweet	Indigenous	Present	
9.	*Kitingisha ndevu*	Sweet	Indigenous	Present	
10	*Kisesa*	Sweet	Indigenous	Abandoned	*Kiroba*
11.	*Dide*	Bitter	Indigenous	Abandoned	*Kiroba*
12.	*Makaniki*	Sweet	Indigenous	Abandoned	*Kiroba*
13.	*Tandika*	Bitter	Indigenous	Present	
14.	*Kanungu*	Sweet	Indigenous	Abandoned	Rotting
15.	*Mwalim Khamis*	Bitter	Indigenous	Present	
16.	*Mwalim Nuru*	Bitter	Indigenous	Present	
17.	*Momuonage*	Sweet	Indigenous	Present	
18.	*Sinawangu*	Bitter	Indigenous	Abandoned	Low yield
19.	*Naliendelee*	Sweet	Introduced	Present	
20.	*Namikonga*	Sweet	Indigenous	Present	
21.	*Kitumbua*	Sweet	Introduced	Present	
22.	*Kigoma red*	Bitter	Introduced	Present	

Data from the Table 4 show that majority (63.6%) of the varieties were sweet while (31.8%) were bitter and (4.5%) was either sweet or bitter depending on its stage of maturity. The data further showed that introduction of *Kiroba* variety was the major cause for the disappearance of varieties (57%), the remaining being rotting (28.5%) and low yield (14.3%) (Table 4).

4.2.3 Processing of cassava

It was learnt (Table 5) that all respondent processed cassava, most of them (88.3%) by fermentation in order to get flour. Direct sun drying to obtain cassava flour was done by 11.7% households while 66.7% of the respondents who fermented cassava did not have any specific reason, they just did it because it was how they saw their parents doing, Cassava was fermented by 5% of respondents on the basis that it is less laborious whereas 11.7% of the respondents did it to improve palatability, 1.7% fermented cassava in order to save time and 3.3% of them fermented the root to soften it. All those who fermented cassava scraped the mould that grows during fermentation, and 85% among them scraped it in order to improve colour and remove the mould which they called "*funga*". The remaining did it just because they saw their parents doing. According to Odunfa, 1985 During the first stage (fermentation) of *gari* production, the bacterium *Corynebacterium manihot* attacks the starch of the roots, leading to the production of various organic acids (such as lactic and formic acids) and the lowering of substrate pH. In the second stage, the acidic condition stimulates the growth of a mould, *Geotrichum candida*, which proliferates rapidly, causing further acidification and production of a series of aldehydes and esters that are responsible for the taste and aroma of *gari*. However, from these results it was gathered that inheritance of the practice and palatability were the primary reasons for fermenting cassava in Tongwe village.

Most of the respondents (81.3%) agreed that there was a difference between fermented and direct sun dried cassava flour, while 13.3% among them said these two products differed in colour, 38.3% attributed the difference to taste, 18.3% to both colour and taste and 11.7% to texture (Table 5).

A big proportion of the respondents (85%) preferred fermented cassava flour over direct sun dried one probably because they did not have another option. Only 5 % preferred direct sun dried flour and the remaining 10% had no preference that meant they could take either of the two. Mortar and pestle was used by 91.7% to grind the flour and 8.3% used hammer mill for grinding cassava to make flour.

Table 5: Respondent's opinion on methods, equipment and differences between cassava flour (n=60)

Variable	Number (n)	Percent
Process cassava		
Yes	60	100.0
No	0	0.0
Method of processing		
Fermentation	53	88.3
No fermentation	7	11.7
Reasons for fermenting		
Learnt from parents	40	66.7
Less laborious	3	5.0
To improve palatability	7	11.7
To save time	1	1.7
To soften the root	2	3.3
Scraping the mould after fermentation		
No	7	11.7
Yes	53	88.3
Reasons for scraping the mould		
Learnt from parents	2	3.3
To remove mould and improve the colour	51	85.0
Differences between fermented and non fermented flour exist		
Yes	49	81.3
No	11	18.3
Source of differences		
Colour	8	13.3
Taste	23	38.3
Colour and taste	11	18.3
Texture	7	11.7
Product preference		
Non fermented	3	5.0
Fermented	51	85.0
Any	6	10.0
Machine used for grinding cassava into flour		
Hammer mill	5	8.3
Mortar and pestle	55	91.7

This can be explained only by the fact that the village is located in remote area where there is no electricity, explaining therefore why hammer mills commonly used in this country were not available. However, there could be diesel-engine operated hammer mills but this could also be limited by low household income that made them unable to purchase one for the village.

4.2.4 Drying time for fermented cassava

The results from Table 6 showed that 41.7% of the interviewee reported that it took 7 days to dry fermented cassava flour during rainy season while others reported that it took 5 days (28.3%), 4 days (15%) 6 days (6.7%), 3 days (5%) and 3.3% said it took 2 days.

Table 6: Respondent's opinion on time taken to dry fermented cassava during dry and wet seasons (n=60)

Variable	Number (n)	Percentage
Time taken to dry casava during rainy season (days)		
2	2	3.3
3	3	5.0
4	9	15.0
5	17	28.3
6	4	6.7
7	25	41.7
Time taken to dry cassava during dry season (days)		
1	4	6.7
2	30	50.0
3	22	36.7
4	3	5.0
5	1	1.7

During dry season most of respondents (50%) said it took 2 days and that was what was experienced during my study. There were also a big proportion of respondents (36.7%) who reported that it took 3 days and this was dependent on the intensity of the sun.

However, drying could range from 1 to 7 days depending on season as well as the size of the cassava pieces that were to be dried. Generally it was noted that drying of fermented cassava took 4-7 days in the rainy season and 2 - 3 days during the dry season (Table 6).

4.2.5 Uses of cassava

Table 7 summarizes information on the uses of fresh cassava and cassava flour. In the fresh form cassava was used for sale (51.7%), but also as human food (41.7%) in the households.

Table 7: Respondent's opinion on uses of cassava (n=60)

Variable	Number (n)	Percentage
Uses of fresh cassava		
Human food only	25	41.7
Animal feed*	3	5.0
Fish feed	1	1.7
Sale	31	51.7
Uses of cassava flour		
Sale	0	0.0
Dry and keep future use	46	76.7
Both	14	23.3
How to use the flour		
To make thin porridge	0	
To make stiff porridge	25	41.7
Both	35	58.3
Feeding infants with food prepared from cassava flour		
Yes	36	60.0
No	24	40.0

* Animal feed include feed for pigs and other animals

Just a small fraction of cassava produced was used as livestock feed (6.7%). Of a total production of 87 million tonnes annually in Africa, only 6 percent is used in livestock production mainly in traditional systems (IFAD and FAO, 2000). When milled into flour, it was a form that was meant to extend shelf life for future use as reported by 76.7% of the households. In the remaining fraction of the households (23.3%) it was intended for both sale and storage for future use. In Africa, about 70% of cassava production is used as food (Cortés *et al.*, 2002). In the early 2000s, 95% of the total cassava production after accounting for waste was used as food in Africa. By contrast, 55% of total production in Asia and 40% in South America are used as food (Nweke, 2004). Again, flour is one of the major forms of use of cassava. Research to improve cassava utilization should address this form of use, since there is a regular surplus of cassava in most cassava producing countries (Tonukari, 2004). In year 2004/05, the annual total production of cassava in Tanzania was 1.85 million metric tonnes on dry weight basis while in year 2005/06 it was estimated to be 2 million metric tonnes (Kilimo Trust, 2007).

About 58% of the respondents in Tongwe used the flour for making both thin and stiff porridge and 41.7% used it for making stiff porridge only. Feeding of infants with food prepared from cassava flour was done by 60% of the households while the remaining 40% did not use them in this form. This underscores the importance of this staple in the nutrition of infants and children. If not well prepared to include potential protein sources, protein deficiency is likely to occur in some households. Cassava contains a small amount of calcium. It is relatively rich in vitamin C (35mg per 100g fresh weight), and contains traces of niacin and vitamins A, B_1, and B_2, but the amount of thiamine and riboflavin are negligible (Onwueme, 1994). Therefore, it is important to supplement cassava with other food if it has to be used for infants and children to correct for deficient nutrients.

4.2.6 Marketing and prices of cassava

Table 8 summarises information regarding marketing and price of cassava. Most of the respondents (80%) agreed that there was a problem of market for cassava and cassava flour. Twenty percent did not have that kind of problem not because they had their means of marketing but because they did not have any surplus for sale. Around 28.3% of the interviewees did not know the price of fresh cassava because they were not selling or buying it while 26.7% said it was 75 Tsh/kg.

Table 8: Respondent's opinion on marketing and prices of cassava (n=60)

Variable	Number (n)	Percentage
Marketing problem exist		
Yes	48	80.0
No	12	20.0
Price of fresh cassava		
Do not know	17	28.3
120Tsh/kg	11	18.3
100Tsh/kg	2	3.3
86Tsh/kg	12	20.0
75Tsh/kg	16	26.7
60Tsh/kg	2	3.3
Price of cassava flour		
Do not know	53	88.3
600 Tsh/kg	1	1.7
500 Tsh/kg	2	3.3
400 Tsh/kg	2	3.3
300 Tsh/kg	1	1.7
200 Tsh/kg	1	1.7
Price of cassava chips		
Do not know	12	20.0
150sh/kg	42	70.0
130sh/kg	4	6.7
120sh/kg	2	3.3

Price of cassava chips was 150 Tsh/kg as reported by the majority (70%). 20% did not know what the price of chips was but was rarely lower than 130 Tsh/kg (11% of respondents). Most of the respondents (88.3%) did not know what the price of cassava flour because they did not usually sell or buy this product due to adequate domestic production.

4.3 Cyanide Level in Cassava Flour

4.3.1 Effect of processing method on cyanide level of cassava

Table 9 shows the effect of processing method on cyanide level of cassava. The means in the table represent the residual cyanide levels in five different cassava varieties processed by four different methods. Appendix 4c shows the differences in HCN level for the five varieties.

Table 9: Effects of processing method on cyanide level of cassava

Treatment	Mean mg HCN kg^{-1} (DWB)
Chipping	7.96^{c}
Grating	6.79^{d}
Direct sun drying	9.90^{a}
Dry fermentation	8.96^{b}

Means bearing different superscript are significantly different (P<0.05)

All treatments differed significantly (P<0.05) from each other in reducing cyanide in cassava, As shown in the table, grating had lowest cyanide level followed by chipping, dry fermentation and finally direct sun drying, in increasing order.

Raji *et al.* (2008) reported that after processing cassava by chipping-drying-milling-pelleting-steaming the residual cyanide was 14.32 mg/100 DWB and grating-dewatering-pelleting-steaming it was 10.13 mg/100g DWB (Essers, 1995). Cyanogens removal by solid state fermentation appeared more effective than sun drying alone (Essers, 1995: Essers *et al.*, 1996). According to Cardoso *et al.* (2003) to produce cassava flour of 10 mg/kg HCN (FAO safe level) it requires to start with sweet cassava containing 16 mg/kg HCN for sun drying only and 32 mg/kgHCN for heap fermentation. In the research to investigate the effect of processing between slicing, grating and reconstitution of starch and fibre, grated cassava flour had the lowest HCN level compared to others (Sakyi-Dawson *et al.*, 2006). This shows the benefit of grating in cyanide removal arising from the size reduction that facilitates interaction between linamarin and linmarase.

In Southern, Eastern and Central Africa where cassava flour is made by sun drying and heap fermentation, there is high retention of cyanide in flour after processing (Cardoso *et al.*, 2003). Nweke (2005) suggested that fermentation is not essential for the elimination of cyanogens in the preparation of *gari* because grating, pressing, pulverizing and sieving steps reduce cyanogens to such low levels safe for human consumption. Crushing before drying improves cyanogens removal by 22% in laboratory analysis and 12% in field trial Pounding cassava to small pieces in traditional mortar and pestle prior to drying was the most efficient method providing 90% removal of cyanogens (Bainbridge *et al.*, 1998). The traditional method of grating cassava is by pounding in a mortar with pestle (Nweke, 2005).

The cassava processing technology which consists of power graters, water presses and sun drying mats produces a high quality cassava flour which is white, odourless and contaminant free. The process is rapid, producing safe flour within 2 days compared with 7–10 days for traditional means of processing and the process efficiently removes cyanogens from bitter varieties to levels below international safety levels (Kolijn *et al.*, 2002). Cassava cyanide can be removed or reduced substantially by simple traditional processing techniques, which include drying, boiling, roasting, shredding or grating, and the de-watering of pulp and fermentation of tissue (Ntonga, 2003).

4.3.2 Cyanide level from household samples

Table 10 shows cyanide content obtained by analysing 60 cassava flour samples obtained from Tongwe households. This ranged from 1.25 – 23 mg HCN/kg DWB for both dry and wet season samples.

The mean HCN content was 10.00 and 7.38 mg HCN/kg DWB for dry and wet season respectively. This showed that the dry season samples had significantly higher mean HCN ($p<0.05$) content than the wet season samples. The wet season mean of 7.38 mg HCN/kg flour was below the FAO limit of 10 mg HCN/kg flour, the dry season mean was 10 mg HCN/kg which was just at the FAO limit. However, when assessed by individual samples, it showed that 50% of the dry season samples had mean above the limit whereas only 27% of the wet season samples were unsafe for consumption (i.e. mean above 10 mg HCN/kg). The results therefore stress the need for slow drying that is also supported by the literature, to produce safe product caused by slow drying that encourages fermentation.

Table 10: mg HCN/kg for cassava flour from Tongwe household

Sample number	Dry season mg HCN/kg	Wet season mg HCN/kg
1	12.7	6.4
2	10.1	6.8
3	5.1	3.6
4	2.5	11.1
5	9.7	5.0
6	10.2	5.0
7	14.2	10.0
8	18.9	2.5
9	11.6	1.3
10	22.9	12.8
11	23.0	10.2
12	11.7	5.2
13	5.2	2.5
14	7.5	12.8
15	8.6	8.6
16	10.0	7.7
17	2.5	2.5
18	12.6	4.8
19	12.1	17.5
20	16.5	3.8
21	3.8	15.5
22	5.2	7.7
23	2.6	6.3
24	9.1	3.8
25	10.2	3.8
26	2.5	5.0
27	7.8	14.1
28	5.2	3.8
29	13.7	9.9
30	12.5	11.3
Mean:	10.0	7.3
Variance:	30.62	18.30
Standard Deviation:	5.53	4.27

In 2004 cassava flour samples obtained from various African countries and Indonesia had a total cyanide content varying from 13-131mg HCN/kg (ATSDR, 2008). According to Mlingi (1996) cyanogens level in cassava flour collected from households in Tanzania made from normal sized ''*makopa*'' was 4 – 9 mgHCN/kg DWB. Charles *et al.*, 2005 reported that in the study of five cassava genotypes the HCN content ranged from 8.33 - 28.8 mgHCN/kg DWB which are within the range of this study.

4.4 Sensory Evaluation

Table 11 shows the means for 5 point hedonic tests done in Tongwe and SUA. Most treatments differed significantly ($P<0.05$) from each other in all parameters investigated i.e. appearance, colour, taste, smell and overall acceptability (Table11) Rating of parameters was 5 = Like extremely, 4 = Like moderately, 3 = Neither like nor dislike, 2 = Dislike moderately and 1= Dislike extremely. Stiff porridge prepared from flour obtained by chipping fresh cassava using a chipping machine ranked top in all aspects. The overall acceptability showed that chipped product was the most preferred followed by direct sun-dried then grated product and finally the fermented product.

Table 11: Means for 5-Point hedonic test for stiff porridge from different treatments

Treatment	Appearance	Colour	Taste	Smell	Overall acceptability
Chipped	3.68^{a}	3.90^{a}	3.92^{a}	3.82^{a}	3.90^{a}
Grated	3.66^{a}	3.40^{b}	3.54^{b}	3.46^{c}	3.54^{c}
Direct sun-dried	3.64^{b}	3.50^{b}	3.46^{b}	3.60^{b}	3.70^{b}
Dry fermented	2.30^{c}	2.02^{c}	2.10^{c}	2.16^{d}	2.22^{d}

Means bearing different superscript in a column are significantly different ($P<0.05$)

In terms of appearance and taste, grated product ranked higher than direct sun dried one next to chipped, and for colour and taste of direct sun dried stiff porridge was more preferred than the grated product. As it has been shown in the above table, chipping led and fermented was the last in all parameters investigated.

The means for five point hedonic testing (Table 11) were obtained by allowing two different groups (SUA group and Tongwe group) of panellist at different times to do the test, therefore unpaired t-test was done to see weather there was any difference between two groups, it was noted that variation between groups was not significant ($P>0.05$).

4.5 Identification of Mycotoxin Producing Organisms in Fermented Cassava Flour

Figs. 2 and 3 show a Petri dish containing mould that has been grown in fermented cassava flour and the picture of mucor which was taken under microscope. From the examination of the growth, fermented cassava flour was accompanied by massive growth of fungi. Microscopic examination showed further that growth of only one type of fungi as depicted by morphological characteristics was observed. Examination of this growth revealed that the type of fungi involved was *Mucor spp* judged from morphological appearance of the reproductive structures.

Figure 2:Petri dish containing *Mucor*.

Figure 3: Picture of *Mucor* under microscope.

Peeled cassava roots appear white in colour (Fig. 4) and normally turn black after being left to ferment for three days. This is caused by mould growth and enzymic browning (Fig. 5) and rapid post-harvest accumulation of phenols, especially scopoletin which in the presence of oxygen forms blue, black and brown pigments as reported by CIAT (2001a). In traditional processing the black growth (mould) is removed by scraping the fermented roots by using a knife. The scraped root (Fig. 6) is soft with characteristic smell which is then allowed to dry in the sun before it is ground to flour. The scrape (Fig. 7) is usually significant in weight and leads to loss of edible portion. Although fermented cassava flour is white in colour, the stiff porridge prepared from it appears dark (Fig. 8) compared to stiff porridge prepared from chipped or grated cassava flour (Fig. 9).

Figure 4: Peeled cassava roots.

Figure 5: Fermented cassava roots.

Figure 6: Scraped fermented cassava roots.

Figure 7: Scrapes removed from fermented cassava roots.

Figure 8: Stiff porridge prepared from fermented cassava flour.

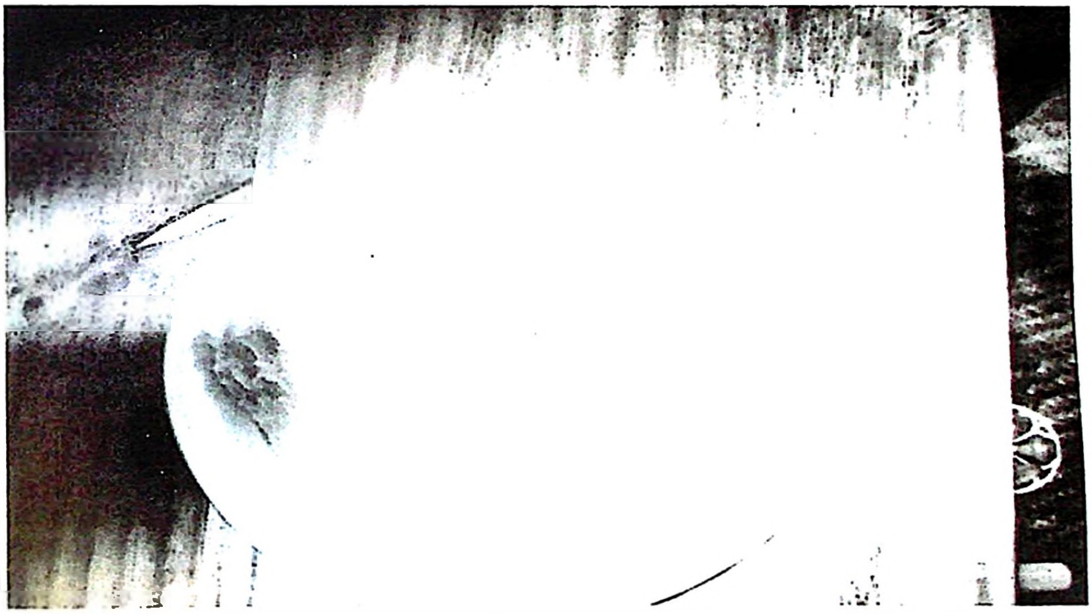

Figure 9: Stiff porridge prepared from unfermented cassava flour.

Mould predominating in fermented product yielding dark-coloured. is a consequence growth of *Mucor spp* (Essers and Nout, 1989). Microbial activity is instrumental which leads to reducing the potential toxicity of cassava during solid-substrate fermentation and effectiveness varies considerably between species of microorganism applies. These genera of fungi involved include *Mucor spp, Geotrichum, Neurospora* and *Rhizopus oryzae* (Esser *et al.*, 1995a). *Mucor raremosus* decreases linamarin by up to 7% (Essers *et al.*, 1995b). In this regard, microbial growth of this type will not lead to production of mycotoxins in the product since this study as well as others did not reveal the presence of mycotoxin producing organisms.

Fagbemi and Ijah (2006) reported that, *Mucor, Rhizopus, Penicillium* and *Aspergilllus* were found to be associated with the fermentation process. In Asia mainly moulds of genera *Aspergillus, Rhizopus, Mucor, Actinomucor* and *Neurospora* are used in manufacture of fermented foods (Leinster, 1990). The most important contribution of microorganisms (*Mucor, Rhizopus* etc) to linamarin decrease in solid state fermentation of cassava is their cell wall-degrading activity, which enhances the contact between endogenous linamarase and linamarin (Essers *et al.*, 1995b) leading to the degradation of the glucosides as detailed by Bokanga (1996). It should be also noted that his fermentation is beneficial to the consumer from the fact that it increases the protein content of the final products 3 to 8 times as argued by Amey (1987). Therefore, for places that are dominant cassava eaters this is the fact that needs to be integrated into the eating habit so that it can add to the low protein content of the root and food mixture since there will be an increase of between 1.5 - 4% and 3 – 8%.

After screening 30 samples, Essers (1995), revealed that there were no mycotoxins detected. According to Muzanila *et al.* (1999) there was no mycotoxin detected in Tanzania cassava samples prepared by solid state fermentation. The products of mould fermented cassava flour have been reported to be safe (Thambiraj, 1989). This supports the fact that although Tongwe residents have consumed mouldy fermented cassava products for decades, nothing has been reported yet in the country health reports as negative effect on their health. Growth of *Mucor* observed in the study is usually not associated with mycotoxin production and could be beneficial in lowering HCN content in the products.

4.6 Assessment of Quantitative Loss of Cassava Due to Processing

Table 12 shows the mean percentage losses for different processing methods Results showed that there were significant differences ($p<0.05$) in percentage losses when different methods of processing cassava roots into flour were used. It seems that traditional methods used i.e. dry fermentation and sun drying alone was more economical in terms of flour yield compared to the improved processing methods like chipping and grating.

Table 12: Mean percentage losses for different processing methods

Method	Mean*
Chipping	69.73^{a}
Fermentation	51.83^{b}
Sun drying only	54.14^{b}
Grating	67.28^{a}

*Each mean represent 6 different preparations
Mean with different superscript are significantly different ($p<0.05$)

The loss could be due to the machine itself because during chipping large pieces of cassava remained unprocessed which cannot dry as fast as chips do, and in some cases they tended to ferment due to long time taken in the drying. Also, there is some processed cassava left in the machine which can only be removed by washing the machine. All these left overs contributed to the total loss experienced at the end of the processing.

For the case of fermentation, except for mould scraping which was normally done very carefully there was no other possible loss because the roots to be fermented were large such that it was not easy to lose them during the process. In processing, direct sun drying of cassava, cassava pieces are usually left where they are, whether on the roof or raised platform from the first day until they are completely dry. This helps to avoid losses that are usually involved in the transfer from the drying place to the storage place, especially when this transfer is repeated for several days during the drying period.

4.7 Assessment of Scraping Losses during 'Bada' Production in Tongwe Village

The losses encountered during scraping of fermented cassava used in 'bada' production are as shown in Table 13. The results showed that the mean losses encountered during scraping were 25% of the peeled root. From this it is obvious that this method contribute to loss that could be easily avoided.

Table 13 Scraping losses of traditionally fermented cassava in Tongwe village

Variety	Scraping losses %
Variety 1	36.00
Variety 2	28.00
Variety 3	16.00
Variety 4	20.00

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Findings from household survey

In the household survey conducted in Tongwe village, it has been learnt that cassava is a very important crop grown in this village and is a staple food to the majority of the households. It is processed in every household to get flour, fermentation being the most popular method as an inherited practice. It seems in Tongwe and probably other cassava eating areas in Muheza district that the dark coloured *ugali* is not liked but has been a common food simply because of lack of an alternative way of getting white-coloured fermented flour for *ugali* that bears the sour taste.

Most of the households used mortar and pestle for pounding cassava into flour, which was very laborious and time consuming. Generally, it was noted that it took 2 to 3 days to dry fermented cassava during dry season and 5 to 7 days in rainy season. Smoking was another way of drying cassava during heavy rains which was only used if someone did not prepare and store enough chips prior to rainy season. In that case normally there was no sun drying during rainy season so there is a need to investigate the safety of smoked product used in Tongwe during this time because the safety of smoked product is largely dependent on the type of fire-wood used to produce the smoke.

In Tongwe only a quarter of the respondents sold their processed product and normally was in the form of chips not flour and a half sold raw cassava. Most of the respondents mentioned the problem of marketing raw cassava and its products and this was confirmed by most of them not knowing the price of cassava products Therefore there is a need of helping them to strengthen the marketing process in general.

Another interesting issue is about the threat of disappearance of local cassava varieties, except for *kiroba* and *kibandameno* all other varieties can only be found in 1 or 2 households and there are some farmers especially young people who have only *kiroba*.

5.1.2 Findings from the experiment

In the study of evaluating the effectiveness of four methods of processing, i.e., dry fermentation, direct sun drying, grating and chipping, it has been concluded that the two improved methods (chipping and grating) are more effective than the traditional methods (dry fermentation and direct sundrying), but the former has high losses due to processing compared to the later. However, all the four methods did not prove to be able to reduce the cyanide in bitter cassava to levels below WHO safe level of 10 mg HCN/kg. Therefore, it is advisable to grate and then ferment bitter cassava variety as in the processing of *gari*.

Microbiological analysis revealed that *Mucor* was predominant species in fermented cassava flour found in Tongwe. The products of mould in fermented cassava flour have been reported to be safe for human consumption.

The sensory evaluation conducted in Tongwe and SUA favours the new methods (grating and chipping) over the traditional methods (dry fermentation and direct sun drying). Therefore, in order to catch the consumers acceptability in marketing their products, people in Tongwe need to have more chipping and grating machines and a hammer mill, because currently they have to take dried grated and chipped cassava to maize milling machines far away from their industry or use mortar and pestle to pound processed cassava into flour. This is laborious and time consuming when talking of large scale cassava processing and marketing so as to achieve the goal of poverty reduction in Tongwe village and Tanzania.

Generally, this study revealed that flour made from improved methods (grating and chipping) is superior compared to that processed by traditional methods (direct sun drying and dry fermentation). In terms of effectiveness in cyanide reduction, grating is leading and in terms of individual preferences chipping is the best followed by grating. However, traditional methods were more economical in processing losses and that there were no mycotoxin-producing organisms in fermented cassava flour. Both traditional and improved methods therefore produce acceptable products worth encouraging if losses are minimized. The only limitation lies in the dark colour that reduces the number of consumers if the fermented flour is sold in areas where this traditional fermentation technology is lacking.

5.2 Recommendations

From the survey, it is recommended that Tongwe villagers should be advised on the importance of maintaining their local cassava varieties and if possible provides them assistance to acquire their own hammer mill for the cassava processing to minimize contamination of their cassava flour by other flours that may accidentally mix with this cassava flour during milling.

From processing experiment it is recommended that in order to process safe cassava flour from bitter varieties, people in Tongwe need to be advised on adopting the procedure of making *gari*, which involves both grating and dry fermentation since dry fermentation has been found to be safe. Also, a research need to be conducted to evaluate the safety of smoked product since it has been mentioned by most households as their alternative way of drying cassava during heavy rain season.

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APPENDICES

Appendix 1: Household questionnaire on cassava processing

Date of interview.......................................

Region/District...

Division..

Ward...

Village..

Sample number...

Name of respondent...................................

1.0 Age of respondent ....Years

2.0 Level of education

1= No formal education [ ]

2= primary education [ ]

3= secondary education [ ]

4= adult education [ ]

5= others (specify)...

3.0 Occupation of respondent

1= Farming [ ]

2= paid employment (specify)..

3= business [ ]

4= others (specify)...

4.0 If farming, do you have cassava plot?

1= yes [ ]

2= no [ ]

5.0 If yes, what is the acreage?

1= less than one acre [ ]

2= one acre [ ]

3= More than two acre (specify)..

6.0 Do you process cassava?

1= yes [ ]

2= no [ ]

7.0 If yes, what kind of processing?

1= fermentation [ ]

2= direct sun drying [ ]

8.0 If fermentation, why do you ferment cassava?

1= to improve palatability [ ]

2= to reduce bitterness [ ]

3= others (specify)...

9.0 Do you scrap the mould before grinding?

1= yes [ ]

2= no [ ]

10.0 If yes why?

1= to remove dirty

2= It is what I learnt from my parents

3= others (specify)...

11.0 How long does it take to dry (during dry season) processed cassava?

1=1 day [ ]

2=2 days [ ]

3=3 days [ ]

4=4 days [ ]

5=5 days [ ]

6= more than 5 days (specify)..................

12.0 How long does it take to dry (during rain season) processed cassava?

1=1 day [ ]

2=2 days [ ]

3=3 days [ ]

4=4 days [ ]

5=5 days [ ]

6= more than 5 days (specify)..................

13.0 What equipment do you use for grinding/milling?

1= mortar and pestle [ ]

2= hand stone [ ]

3= others (specify)...

14.0 What else do you do to the raw cassava?

1= feed animals [ ] (specify)......................

2= sell [ ]

3= others (specify)..

15.0 What do you do to the processed cassava flour?

1= dry and keep for future use [ ]

2= sell [ ]

3= both [ ]

16.0 How do you use the flour?

1= to make stiff porridge [ ]

2= to make thin porridge [ ]

3= both [ ]

4= others (specify)..

17.0 Does the flour from fermentation differ from that of direct sundrying?

1= yes [ ]

2= no [ ]

18.0 If yes what are the major differences

1= colour

2=taste

3=smell

4=texture

19.0 Which process produce flour do you prefer most?

1= fermentation [ ]

2=direct sundried [ ]

20.0 Do you feed your infants with food prepared from the above flour?

1=yes [ ]

2=no [ ]

21.0 Do you get difficulties in disposing the cassava you have cultivated?

1=yes [ ]

2=no [ ]

22.0 On average what are the prices of cassava and cassava products?

Product	Fresh cassava	Cassava chips	Cassava flour
Price			

Appendix 2: Sensory evaluation form for (SUA)

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

In front of you are four samples of cassava stiff porridge. Kindly, you are required to taste them in order given, please rinse your mouth with water before tasting each sample. Give comment for each sample on the following parameters -:

1. Appearence
2. Colour
3. Taste
4. Smell
5. Overall acceptability

Use the following in rating the above parameters-:

5 – Like extremely

4 – Like moderately

3 – Neither like nor dislike

2 – Dislike moderately

1 – Dislike extremely

Sample	Appearance	Colour	Taste	Smell	General acceptability
504					
128					
309					
245					

THANK YOU

Appendix 3: Fomu maalum ya kuonja aina tofauti za ugali wa muhogo(TONGWE)

Jina:............................ Jinsia :..................... Tarehe:...............

Mbele yako kuna aina tano za ugali wa muhogo, tafadhali onja kisha utoe maoni yako kuhusu mambo yafuatayo -:

6. Muonekano
7. Rangi
8. ladha
9. Harufu
10. Maoni kwa ujumla

Tumia vigezo vya nabmari kama ifuatavyo-:

5 – Nimeipenda sana

4 – Nimeipenda kiasi

3 – Sijapenda wala sijachukia

2 – Sijaipenda kiasi

1 – Sikuipenda sana

Aina ya ugali	muonekao	rangi	Ladha	harufu	Maoni kwa jumla
504					
128					
309					
245					

AHSANTE

Appendix 4a: Table of mgHCN/kg for dry season

Variety	Treatment			
	Chipped	Grated	Direct sun dried	Fermented
Mamuonage (sweet)	6.00	3.58	8.31	7.19
Mamosi (sweet)	3.50	2.38	4.86	3.60
Kiroba (sweet)	3.70	3.56	5.90	4.70
Kiroba (bitter)	9.65	8.29	11.98	10.75
Mwalimunuru (bitter)	16.95	16.48	18.80	17.66

Appendix 4b: Table of mgHCN/kg for wet season

Variety	Treatment			
	Chipped	Grated	Direct sun dried	Fermented
Mamuonage (sweet)	4.77	4.79	7.19	7.18
Mamosi (sweet)	3.57	1.21	4.80	4.84
Kiroba (sweet)	3.62	2.38	5.99	4.76
Kiroba (bitter)	10.87	8.35	10.84	10.77
Mwalimunuru (bitter)	17.05	16.90	20.37	18.22

Appendix 4c: Table of mean HCN different varieties DWB

variety	Mean mg HCN kg^{-1}
Mamuonage (sweet)	6.12^{b}
Mamosi (sweet)	3.59^{b}
Kiroba (sweet)	4.24^{b}
Kiroba (bitter)	10.19^{b}
Mwalimu nuru (bitter)	17.80^{a}

Means bearing different superscript are significantly different ($P<0.05$)

Appendix 5: ANOVA Table for cyanide level

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	1091.830	272.958	762.7759	0.0000
4	Factor B	3	53.556	17.852	49.8867	0.0000
6	AB	12	3.833	0.319	0.8927	
-7	Error	20	7.157	0.358		
	Total	39	1156.376			

Appendix 6a: ANOVA Table for appearance

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	24	13.270	0.533	0.5216	
4	Factor B	3	69.400	23.133	21.8239	0.0000
6	AB	72	52.850	0.734	0.6925	
-7	Error	100	106.000	1.060		
	Total	199	241.520			

Appendix 6b: ANOVA Table for colour

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	24	29.220	1.217	1.0082	0.3774
4	Factor B	3	100.615	33.538	29.8119	0.0000
6	AB	72	44.260	0.615	0.5464	
-7	Error	100	112.500	1.125		
	Total	199	286.592			

Appendix 6c: ANOVA Table for taste

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	24	21.370	0.890	0.8521	
4	Factor B	3	94.975	31.658	30.2951	0.0000
6	AB	72	47.150	0.655	0.6267	
-7	Error	100	104.500	1.045		
	Total	199	267.995			

Appendix 6d: ANOVA Table for smell

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	24	18.730	0.780	0.8576	
4	Factor B	3	83.960	27.987	30.7546	0.0000
6	AB	72	44.790	0.622	0.6836	
-7	Error	100	91.000	1.910		
	Total	199	238.480			

Appendix 6e: ANOVA Table for overall acceptability

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	24	28.880	0.870	0.9355	
4	Factor B	3	86.880	22.960	31.1398	0.0000
6	AB	72	44.120	0.613	0.6589	
-7	Error	100	93.000	0.930		
	Total	199	244.880			

Appendix 7: Table of percentage losses for different processing methods

Method of processing	Percentage losses					
	1	2	3	4	5	6
Direct sundrying	72.20	68.15	46.40	50.00	50.00	37.50
Grating	69.40	60.70	70.60	71.80	67.7	62.50
Fermentation	50.00	50.50	61.00	57.10	50.00	52.90
Chipping	62.50	75.0	82.10	65.60	57.50	75.70

Appendix 8: Table of percentage losses due to scraping of fermented cassava

Cassava variety	Wt of scraped cassava	Wt of waste	Percentage waste	Mean Percentage waste
Variety 1	34.00	16.00	32.00	36
	30.00	20.00	40.00	
	32.00	18.00	36.00	
Variety 2	39.00	11.00	22.00	28
	36.00	14.00	28.00	
	33.00	17.00	34.00	
Variety 3	40.00	10.00	20.00	16
	44.00	6.00	12.00	
	42.00	8.00	16.00	
Variety 4	43.00	7.00	14.00	20
	40.00	10.00	20.00	
	37.00	13.00	26.00	