THE EFFECT OF LOCAL CASSAVA PROCESSING METHODS ON NUTRITIONAL AND SENSORY ATTRIBUTES OF CASSAVA FLOUR: A CASE STUDY OF NEWALA DISTRICT

BY

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ABSTRACT

A study was carried out in Newala District to investigate the effect of different local cassava processing methods on cyanogenic glucosides level, nutrient retention and colour of cassava flour. Specifically the study was aimed at identifying different local cassava processing methods, examining the effect of local processing methods on residual cyanogenic glucosides in the cassava flours, examining the effect of local processing methods on nutrient retention and color of cassava flour and study the cassava processing and production constraints in the study area. In each study site, information was obtained by focus group discussion, structured questionnaire from 40 households in each village. Samples were collected for laboratory analysis. Results showed high total residual cyanogen levels of about (790 ± 107 mg HCN equivalent/Kg dry weight) and (263 ± 71 mg HCN equivalent/Kg dry weight) in flour obtained from both small-size and large-size *makopa* respectively. Cyanohydrin levels were higher (39 ± 5 mg HCN equivalent/Kg dry weight) in *Chinyanya* compared to levels of about (7 ± 2 mg HCN equivalent/Kg dry weight) in the flour from large size *makopa*. *Chinyanya* showed to contain (75 g/100g, starch, 1.3 g/100g protein, 32.8 g/100g vitamin C, 18.7 g/100g moisture and 13.22 pH, *Makopa* showed to contain 80.0 g/100g starch, 2.72 g/100g protein, 24.52 g/100g vitamin C, 12.5 g/100g moisture, at pH 10.28 where as fermented root showed to contain 65.2 g/100g starch, 0.75 g/100g protein, 15.4 g/100g vitamin C, 13.7 g/100g moisture, pH 5.25). These findings confirmed that direct sun-drying of cassava roots is an ineffective method for removal of cyanogenic glucosides as it yields products with relatively high residual levels of cyanogenic glucosides while fermentation of cassava root is an effective method in removal of total glucosides. Apart from colour preference, this study concluded that although wet fermentation showed high nutrient loss, from the health point of view it is an

effective way of reducing cynogenic glucosides level from cassava root, which are dangerous for human health.

DECLARATION

I, Nuria Majaliwa, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has never been submitted for degree award in any other university.

Signature: _____ 2007-11-16

Nuria Majaliwa, Date

(MSc. Candidate)

The above declaration is confirmed

_____ 2007-11-16

Mr V.M. Kimaryo Date

(Supervisor)

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DEDICATION

I dedicate this dissertation to my father Dr. Kudra Majaliwa and my mother Rehema Dossi who laid the foundation of my education.

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LIST OF ABBREVIATIONS

AIDS	-	Acquired Immuno Deficiency Syndrome
AMREF	-	African Medical and Research Foundation
ANOVA	-	Analysis of Variance
AOAC	-	Association of Official Analytical Chemists
ASARECA	-	Association for Strengthening Agricultural Research in Eastern and Central Africa
CIAT	-	Centro International de Agricultura Tropical
CN	-	Cyanide
COSCA	-	Collaborative Study of Cassava in Africa
FAO	-	Food and Agriculture Organization
g	-	Gram
HCN	-	Hydrogen Cyanide
HIV	-	Human Immuno Deficiency Virus
ID	-	Iodine Deficiency
IDRC	-	International Development Research Centre
IITA	-	International Institute of Tropical Agriculture
KCN	-	Potassium cyanide
Kg	-	Kilogram
Kj	-	Kilojoules
mg	-	Milligram
MSG	-	Monosodium Glutamate
NaCN	-	Sodium cyanide

NARS	-	National Agricultural Research Systems
NBS	-	National Bureau of Statistics
NGO	-	Non Governmental Organization
SCN	-	Thiocyanate
s.e	-	Standard Error of the Mean
SUA	-	Sokoine University of Agriculture.
TADENA	-	Tanzania Development Navigation Trust
TAN	-	Tropical ataxic neuropathy
TFNC	-	Tanzania Food and Nutrition Centre
TMS	-	Tropical Manihot Series
µg	-	Microgram
UNICEF	-	United Nations Children's Fund
WHO	-	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Cassava (*Manihot esculenta* (Crantz) is the starchy root crop that is grown almost entirely within the tropics. Although it is one of the most important crops in the tropical countries, it is little known elsewhere, and within the tropics, it is considered to be a low grade subsistence crop (Cook, 1985). Cassava ranks fourth on the list of major food crops in developing countries after rice, wheat and maize (Nwapa, 1986). In Sub-Saharan Africa cassava is grown chiefly as human food, but it is also an important animal feed, and it has several industrial uses. As one of the cheapest sources of food energy, cassava should play a major role in meeting developing countries rising consumption of both food and animal feed.

In Tanzania, cassava is grown in many parts of the country and chief growing areas are Mtwara, Mwanza, Lindi, and Tanga. Cassava is also grown in other parts of the country as a result of Government efforts to stimulate local self-sufficiency in food supply (Berry, 1996; Wyllie and Huxley, 1996); as such, making cassava the most important root crop in the country. Both the tubers and leaves of cassava contain cyanogenic glucosides, which may lead to toxicity if cassava is not properly processed. Its levels depend on the variety of the crop. Thus, to ensure they are safe for human consumption, the cyanogens must be removed or considerably reduced. Depending on the processing method used, the percentage of cyanide reduction varies from 69.85 to 100% (Nwapa, 1986). In order to minimize the cyanogens content, cassava is processed by different traditional methods, which include fermentation (wet and solid-state) and sun drying. However, in solid state

fermentation and sun drying, there is proliferation of spoilage and pathogenic micro-organisms on cassava, some of which may produce mycotoxins. World production of cassava roots grew from 70 million tons in 1960 to 1992 tropical and sub-tropical countries. Between 1961 and 2005, the five major cassava-producing countries in the world are Brazil, Nigeria, Thailand, Zaire and Indonesia.

Tanzania is estimated to produce 6.3 million tons. The total area harvested in the world in 2005 was about 16 million hectares, with 57% of which was in Africa, 25 in Asia, and 18% in Latin America. About 15% of the world's production of cassava is exported to Europe and Japan as either chips or pellets, and Starch. The starch is used in food industries, textiles, paper industries and in beer brewing. The remaining 85% world production is used within the producing countries for food (58%), animal feed (28%), and industrial uses (3%), where the wastage is about 11% (CIAT, 1993).

The area of land planted with cassava is greatest in Africa, but yields are lower than other continents (Silvestre and Arraudeau, 1983). Africa is the only part of the world where per capita food production has been declining in the last two decades although cassava production has nearly doubled during this period (De Bruijn and Fresco, 1999). Most of the cassava in Africa is produced by female farmers for food and is consumed near to where it is grown. There is a growing commercial market for cassava in Africa, and men are gradually being involved in the production of cassava in Nigeria, Ghana and Zaire (FAO, 1995).

Human cassava consumption is greatest in Africa, averaging to 96 kg fresh weight per capita. The highest consumption is found in Zaire with 391 kg annually per capita or 1,123

calories per day (CIAT, 1993). The starchy roots are the most commonly consumed part, but the leaves are also consumed as preferred green vegetable in many cassava-growing communities, especially in Central Africa (Hahn, 1998).

Cassava has long been recognized by many African farmers as an insurance against famine, but its value as a food security crop has been internationally undervalued until recently. In 1986 the late Exccutive Director of UNICEF, James Grant, and described cassava as a poor man's Cinderella. He took the initiative of promoting cassava as household food security crop in Africa (Power, 1986). In Central African countries where cassava constitutes over 50% of the staple food (Nweke 1994) and in the West Africa the attitude towards cassava is positive. It forms part of the culture as expressed in poetry (Nwapa, 1986).

In broad terms, there are three major opportunities that farmers and processors can access. These are high quality cassava flour, cassava starch as a raw material for food and non-food industries and cassava chips for either the domestic livestock feed sector or for export (Bokanga, 1995). Major cassava varieties are diffused in the humid rainforest ecology of Southwestern Nigeria through the National Agricultural Research Systems (NARS) and includes the tropical manihot series (TMS) 30572, 4 (2) 1425 and 30555 originally released by IITA (IITA, 1984; 1987).

1.2 Problem Statement

Although nearly all Sub Saharan countries are famine hit, acceptability of cassava as a rescue crop has failed due to probably the poor quality of cassava products and toxicity. Lack of appropriate cassava processing technologies and enough knowledge on processing

have been the limits to maximum cassava utilization to improve the food security in the region for many decades. Also, little is known about quality that exists for these processed products and hence farmers cannot see the relative benefits of improving processing. Thus, to ensure they are safe for human consumption, the HCN must be removed or considerably reduced (Ayernor, 1998).

1.3 Justification

This study will simulate the local methods for processing of cassava in those selected villages of Newala district and evaluate their effectiveness on cyanogenic glucosides removal, quality of cassava flours, and make recommendations on best traditional cassava processing method that can be adopted in the study area. Improvement of the local knowledge on processing will not only increase the quality and shelf life of the products but also will enhance market option and thus food security.

1.4 Objectives

1.4.1 Overall objective

The overall objective of the study was to investigate the effect of local cassava processing methods to the residual cyanide levels, nutrient retention and colour of cassava flour.

1.4.2 Specific objectives

(i) To identify different local cassava processing methods in study area

(ii) To evaluate the production and processing constraints

(iii) To examine the effect of local processing methods on residual cyanogenic glucosides of cassava flour.

(iv) To examine the effect of local processing methods on nutrient retention and color of cassava flour.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Classification

Cassava plant is a perennial shrub, with a height ranging from about 1-3.5 m depending on the variety and growing conditions. The mature stems and branches are rounded and generally of uniform thickness, not more than 5-7 cm diameter. Cuttings are the main propagation method, but seedlings can also be used although they can take up to 2-3 years to produce mature roots (Doku, 1999).

Cassava (*Manihot esculenta*) belongs to the family *Euphorbeaceae*. This family contains about 300 genera with over 5,000 species, most of which are tropical, including two very important species, the castor plant (*Ricinus communis*) and the para rubber (*Hevea brasiliensis*). Different botanists have classified cassava in different ways. The two species recognized were the poisonous, bitter species, *Manihot esculenta* Crantz and, the sweet non-poisonous species *M.duleis baill.* This classification is based on the cyanogenic glucosides content of roots, considering the sweet species to have lesser cyanogenic glucosides than the bitter species (Doku, 1999).

However, Bourdoux *et al.* (1988), suggested that such a classification can not be useful, as the environment also has an effect on the root toxicity. Drought and low soil fertility status as well as a deficiency of potassium are known to increase the cyanogenic glucosides content, hence the bitterness and toxicity of roots. So in that case, there is a tendency to regard all cassava as varieties of *M. esculenta* Crantz.

2.2 Origin and dissemination

Cassava is the native of South America, with its origin probably being Brazil where it had been an important source of food. It was introduced from Brazil to the tropical areas of Africa, the Far East and the Caribbean Islands by the early Portuguese slave dealers in the 16^{th} and 17^{th} centuries (Jones, 2003). In Africa, cassava is mostly grown on small farms, usually intercropped with vegetables, plantation crops (such as coconut, oil palm, and coffee), yam, sweetpotato, melon, maize, rice, groundnut, or other legumes. The application of fertilizer remains limited among small-scale farmers due to the high cost and unavailability. The roots can be harvested between 6 months and 3 years after planting (IITA, 2002).

2.3 Global cassava production

According to FAO estimates, 172 million tonnes of cassava was produced worldwide in year 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, 2002).

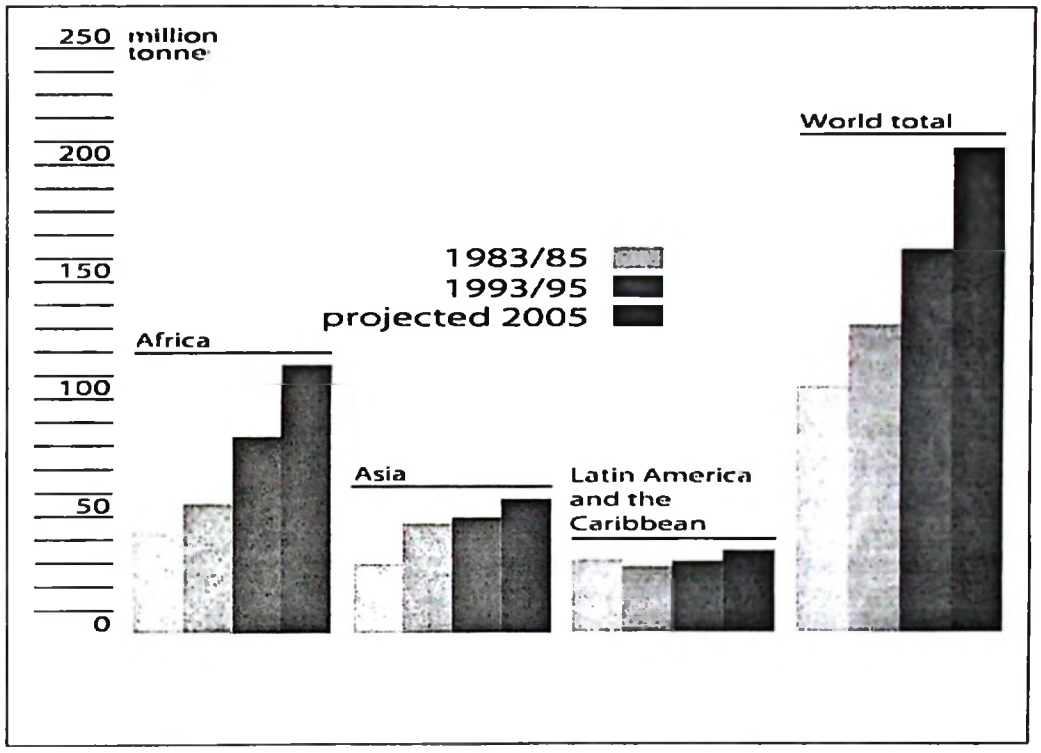

Figure 1: Global cassava production

Source: IITA, (2002)

2.4 Cassava production in Africa

Cassava is produced mainly by small farmers, who are often women heads of households, who generally use traditional farming methods, and live in some of the poorest and most difficult areas of the tropics. The crop offers these farmers several major advantages. Cassava is relatively tolerant of poor soils and seasonal drought and has an unrivaled ability to recover from damage by pests and diseases. In addition, it can be safely left in the ground for 7 months to 2 years after planting and then harvested as needed (IITA, 2005).

2.5 Constraints to cassava production

Cassava production is presently characterized by use of low inputs, rudimentary technology, large post-harvest losses and minimal processing. Associated with these are problems of unreliable supply, uneven quality of products, low producer prices and costly marketing structure (ASARECA, 2006). Historically, cassava had few serious pests and diseases in Africa. However, the situation changed as cassava cultivation intensified and exotic pests were introduced (ASARECA, 2006). The major pests of cassava in Africa are the cassava green mite, the cassava mealy bug, and the variegated grasshopper. The main diseases affecting cassava are cassava mosaic disease, cassava bacterial blight, cassava anthracnose disease, and root rot. Pests and diseases, together with poor cultural practices, combine to cause yield losses that may be as high as 50% in Africa. The production of cassava is dependent on a supply of good quality stem cuttings. The multiplication rate of these vegetative planting materials is very low compared to grain crops, which are propagated by true seeds. In addition, cassava stem cuttings are bulky and highly perishable as they dry up within a few days. As a root crop, cassava requires considerable labor to harvest. Because they are highly perishable, roots must be processed into a storable form soon after harvest. Many cassava varieties contain cyanogenic glucosides, and inadequate processing can lead to chronic toxicity. Various processing methods, such as grating, sun drying and fermenting, are used to reduce the cyanide content (IITA, 2002).

2.6 Chemical and nutritional composition

Various processing methods, such as grating, sun drying, and fermentation, are used to reduce the cyanide content (IITA, 2002). Cassava is an excellent source of dietary energy (565 Kj). The fresh roots have 30-40g/100g dry matter. Protein content is very low, about 1.2g/100g dry weight with fat content even lower, between 0.2-0.5 g/100 g dry weights

(Cock, 2001; Grace, 2004). The vitamin C content ranges between 34-36 mg/100g dry weight. It contains significant amounts of thiamine (vitamin B1) riboflavin (vitamin B2) and Niacin. Cassava roots have higher dietary energy, total carbohydrate and vitamin C content compared to other root crops.

Table 1: Nutrients in cassava roots compared with other food products

Food products	Nutrients						
	Calories per 100g	Protein	Fat	Carbohydrate	Ash	Moisture	Fibre
Cassava tubers (peeled)	127	0.8	0.2	32	0.3	65	0.8
Cassava flour (tapioca)	307	0.5	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

Source: FAO (2000)

Although cassava roots are an excellent source of calories, they lack protein and vitamins. Cassava leaves, however, are rich in protein and vitamins A and B and can be an important part of a well-balanced, nutritious diet. The nutritional composition varies from place to place depending on climate, the type of soil, the crop variety and other factors. Apart from supplying energy and vitamin C, cassava roots are considered poor in nutritional terms. They have been implicated as the major cause of malnutrition in parts of Africa. However, the nutritive deficiencies of cassava need not be a cause for concern, when it is consumed with other supplementary foods such as meat, beans and leafy vegetables (CGIAR, 2002).

Cassava is produced and utilized as human food, predominantly in geographical areas where animal protein supply is inadequate. For that reason, disease associated with protein deficiency such as kwashiorkor is prevalent in those areas, hence many people implicate cassava as the direct cause of malnutrition. However, it has been suggested that, since diseases associated with protein malnutrition are invariably engendered by low intake of poor quality proteins, it is quite justified to consider the high carbohydrate content of cassava as being directly responsible for causing the protein deficiency. At the same time, diets containing high ratios of cassava, can lead to nitrogen imbalance, which can be alleviated by supplementary addition of essential amino acids, particularly methionine and tryptophan (Nartey, 1997).

Cock (2001) stated that it is true that people who consume large quantities of cassava with little protein supplement will be malnourished. The cassava problem as related to "kwashiorkor" disease means that the people with low incomes are prone to consume it in excessive quantities, because it supplies sufficient calories and gives a feeling of satiety in their diets. Therefore many suffer from deficiency of protein and /or vitamins (Grace, 2004).

Apart from this, cassava still has the advantage of being cheap, meaning it can give required energy at low cost. Cock (2001), concluded that increasing protein percentage in a diet deficient in total energy will not alleviate protein deficiency because, the body will be undernourished, and utilize protein in diet as an expensive energy source. Increasing the carbohydrate supply in the diet can increase the protein utilization efficiency. In general cassava can supply a cheap energy source, while other foods are used to supply the necessary proteins, vitamins, minerals and fat. Bokanga (1995), reported that cassava

leaves are also a good source of protein, minerals and vitamins. Cassava is normally subjected to treatments such as soaking in water, grating, grinding, fermenting, roasting, pounding etc. This causes a considerable loss of some elements and vitamins. Doku (1999) reported that almost all vitamins are lost when cassava is processed into gari or kokonte. Vitamin B1, vitamin B2, Niacin and vitamin C of gari and kokonte are lower than that of fresh cassava.

Doku (1999) explained how attempts were made in Nigeria to improve the nutritional value of gari by the addition of minerals and vitamins. It is further suggested that the nutritional value of cassava products such as kokonte flour, yake yake and tapioca could be improved on the same lines as fortified gari or they could be taken with soups and stews of high nutritional value beans. Kokonte are sun dried cassava root pieces. Yake yake refers to steam baked cassava cakes made from dried cassava meal and tapioca is the product made from roasted starch granules obtained from liquid squeezed out of grated cassava roots (Doku, 1999).

Table 2: Estimates of vitamins and mineral content of some cassava products (Milligrams per 100 grams product)

Cassava products	Vitamin B1	Vitamin B2	Niacin	Vitamin C	Calcium
Fresh cassava	0.05	0.04	0.06	34.0	26.0
Gari white	0.00	0.00	0.00	0.00	46.0
Gari yellow	0.00	0.00	0.00	0.00	83.0
Flour and meal	0.00	0.00	0.00	0.00	20.6
Roots and dried after	0.00	0.00	0.00	0.00	0.00
Soaking(kokonte)	0.00	0.00	0.8	0.00	86.1
Cassava cakes	0.06	0.1	0.00	0.00	0.00
Boiled roots	0.00	0.00	0.00	20.33	0.00
Roasted roots	0.00	0.00	0.00	26.46	0.00

Source: Doku (1999)

Table 3: Nutrient comparison of original white and fortified gari (dry weight basis)

Nutrients	Gari	Fortified Gari
Water (g)	8.50	7.30
Protein (g)	1.50	7.90
Fat (mg)	0.10	13.30
Carbohydrate(g)	87.00	77.90
Ca (mg)	45.60	73.30
P (mg)	56.90	140.90
Fe (mg)	2.20	3.30
Thiamin (mg)	0.12	0.24
Riboflavin (mg)	0.04	1.00
Vitamin A (I.U.)	0.00	16.00
Calories	338.00	341.00
Biological Value	47.00	54.00

Source: Doku (1999).

2.7 Cyanogenic glucosides

The presence of cyanogenic glucosides in cassava root is the limiting factor in the use of cassava products for food (Ayernor, 1998). Cassava is a cyanophoric plant meaning that it has the capacity to produce hydrogen cyanide. Cyanophoric plants contain cyanogenic glucosides, and the enzymes which hydrolyse them, in different compartments of their cells (Nartey, 1997). When cellular structure is disrupted, the cyanogenic glucosides are hydrolyzed by the enzyme. A primary concern in the processing of cassava root is the detoxification of the cyanogenic glycosides present in the root. Tapioca root is known to contain between 2 - 395 mg of linamarin/100 kg of fresh root (Bradbury and Egan, 1992; Yeoh and Truong, 1993). These levels vary among species - leading to the appellations sweet and bitter varieties. In the intact root, the linamarin is separated from its hydrolyzing enzyme, linamarase which is located in the cortex of the root. With crushing, however, it is brought in to contact with the substrate, linamarin, which is then hydrolyzed to acetone and hydrogen cyanide. Hydrogen cyanide is heat labile and also water-soluble. Traditional processing methods which included fermentation and sun-drying significantly reduced

cyanogenic glycoside levels (Kemdirim *et al.*, 1995). These methods resulted in reduction of total cyanogens in fresh roots from 91 - 1515 mg/kg to 0.0-11.3 mg/kg, in the prepared foods (O'Brien *et al.*, 1992). Hydrogen cyanide is volatile and crushing to promote cyanogenesis and then release of hydrogen cyanide actually results in a sweeter product since the glucose remains behind (Jones, 1998).

2.7.1 Synthesis and distribution

Linamarin and lotaustralin, usually found in cassava in the ratio of 10 to 1, are synthesized from amino acid valine and isoleucine respectively. Originally, it was thought that cassava produces cyanogenic glucoside in all its tissues, throughout the growth cycle, including sap exudates (Nartey, 1978). Recently, it has been established that the cyanogenic glucosides are only synthesized in leaves and translocated to all parts of the plant, where they accumulate (Ayernor, 1998).

De Bruign (1991) found that there was a decrease of cyanogenic glucosides production in leaves with progressive ageing, and in young expanding leaves the cyanogenic glucosides content of the leaf petioles was much higher than the blades. He also reported that the apical portion of the stem contain relatively high levels of cyanogenic glucosides which decrease towards the base. At the time of harvest of cassava roots, the amounts of cyanogenic glucosides vary from a few milligrams to 250 mg or more per kilogram of fresh roots (Grace, 1977). It has been observed that the cyanogenic glucoside content of the cassava plant is markedly increased by drought and by potassium deficiency. Although some varieties are referred to as "sweet" suggesting that they do not contain cyanogenic glucosides, there are no completely cyanide-free cultivars found so far (Nartey, 1978).

2.8 Cyanide toxicity

Cyanide is a deadly poison, which inhibits enzymes involved in ATP production in cells. Cyanide inhibits a wide range of enzymes, including metal-containing enzymes and haemo proteins with which they react to form stable complexes. Lundquist (1992) reported that cytochrome enzyme (terminal oxidase) in the respiratory chain is susceptible to cyanide inhibition.

Cyanohydrins are the most dangerous form of the cyanogens. Cyanide can react with carbonyl compounds and reduce thiol group and disulphide bonds. Therefore, cyanide ingestion can cause serious physiological hazard (Nartey, 1978). In the blood stream, cyanide is converted to thiocyanate by the enzyme rhodanase. The thiocyanate as such is not harmful. It contains sulphur and is excreted in the urine. This leads to increased demand for sulphur containing amino acids. Thiocyanate also interferes with iodine uptake by the thyroid, resulting to goiter (Delange *et al.*, 1973; Ekpechi, 1993).

According to Lundquist (1992), the lethal dose for hydrogen cyanide varies from 0.5 to 3.5 mg/kg body weight in humans. However, several millions of the people living in the tropics consume cassava on a daily basis without any obvious sign of being poisoned (Bokanga, 1995). Although acute toxicity occurs very rarely, it can cause death in humans. This can result from the consumption of poorly prepared or completely unprocessed cassava roots (Nartey, 1978). Symptoms of acute cyanide poisoning include, abnominal pains, vomiting, mental confusion, muscular paralysis and respiratory stress as cyanide affects the cytochrome oxidase system, which may result into coma (Lancaster *et al.*, 1992).

In general, in malnourished populations, some chronic effects of long term consumption of cassava include, endemic goitre, tropical ataxic neuropathy and cretinism and Konzo disease (epidemic spastic paraparesis) (Mlingi *et al.*, 1991). Tropical ataxic neuropathy is a collective term for disorders which include, lesions in the skin, mucous membranes, optic and auditory as well as peripheral nerves (Osontokun, 1991). Cretinism on the other hand is a condition of stunted growth in children. However, in some areas in Latin America and Asia where cassava consumption is high, no cases of goitre and ataxic neuropathy have been reported (Cook, 1998). These people consume considerable quantities of animal and fish proteins thus have high levels of sulphur amino acids intake, which play a part in cyanogenic glucoside detoxification.

Both the tubers and leaves of cassava contain cyanide, which can be poisonous. Its levels depend on the variety of the crop. Thus, to ensure they are safe for human consumption, the HCN must be removed or considerably reduced. Depending on the processing procedure used, the percentage of cyanide reduction varies from 69.85 to 100%. The tubers are detoxified by hydrolysis of linamarin and lotaustralin by the enzyme linamarin located in the root peels, into HCN (hydrogen cyanide), which is volatile and evaporates rapidly at temperatures above 28^0C. Some measure of detoxification can also be achieved by mechanical disintegration (Numfor *et al.*, 1997).

2.9 Mechanized processes of cassava detoxification

Detoxification of cassava whole tubers (unpeeled), cassava waste, and cassava peel for the removal of residual cyanide can be achieved by fermentation, acid hydrolysis, and fermentation followed by acid hydrolysis.

2.9.1 Fermentation process

2.9.1.1 Washing and grating

The first stage of this process consists of washing the unpeeled cassava tubers which have been previously cut into small sizes, or the cassava waste or cassava peel. The washed cassava samples are then fed through a conveyor to a grater where they are properly grated to specific size.

2. 9.1.2 Fermentation

The grated cassava or the cassava mash is poured into a 400-litre tank, which is constructed from plastic, fiber glass, or such other materials as aluminium. A known quantity of water is added to the cassava mash, mixed thoroughly and left to stand for 24 hours. Because of the toxic hydrogen cyanide given off, it is essential that adequate ventilation is provided (Goosens, 1994).

2. 9.1.3 Dehydration or dewatering

The fermented liquid cassava mash is dewatered, using either a basket centrifuge and hydraulic press or a screw press to produce a thick fermented cassava cake of about 45-47% moisture content.

2.9.1.4 Drying

The fermented cassava cake is normally broken down into small pieces and fed directly into a fried rotary louver dryer at temperatures of about 75°- 100°C where the moisture content is further reduced to a low level in order to give dried cassava cake with a long shelf life.

2.9.1.5 Sieving

The dry cassava cake is sieved using a sieving machine with a mesh aperture of 450 square m-2mm, 630 square m-2mm and 1000 square m-2mm for unpeeled cassava tubers, cassava waste, and cassava peel respectively.

2.9.1.6 Milling and packaging

The oversized particles of cassava cake or grit are milled to the particle size of the sieve, using the Bentall disc attrition-milling machine. The final powdery detoxified cassava products are then collected and packaged in cellophane bags ready for use for ration formulation at rates varying from 40-45 % of the concentrate mixture for poultry (FAO, 1980) The hydrogen cyanide levels of the cassava mash before fermentation, after 24 hours fermentation, and of the final detoxified cassava products are determined using the modified method of the AOAC (1972).

2.9.2 Acid hydrolysis process

In this process, the washing and grating stage adopted in the fermentation process is also used. In acid treatment process, a known concentration of mineral acid, such as concentrated hydrochloric acid previously diluted with water to give a known strength of the acid, is added to the cassava mash, mixed thoroughly and allowed to stand for 2 hours for acid hydrolysis to take place. This is followed by the neutralization of the acid with a known concentration of mineral alkali such as sodium hydroxide for 5 minutes. Dewatering, drying, sieving, milling, packaging, and hydrogen cyanide determination as in the process of fermentation, are also carried out as reported by Shapiro and Toolens (1992).

2.9.3 Fermentation coupled with acid hydrolysis process

The cassava is fermented as described in the fermentation- process, after which it is subjected to the acid hydrolysis process. Dewatering, drying, sieving, milling, packaging, and hydrogen cyanide determination are also carried out. The detoxification processes of cassava (whole tuber, waste, or peel) for the removal of toxic residual cyanide are shown in Figure 2.

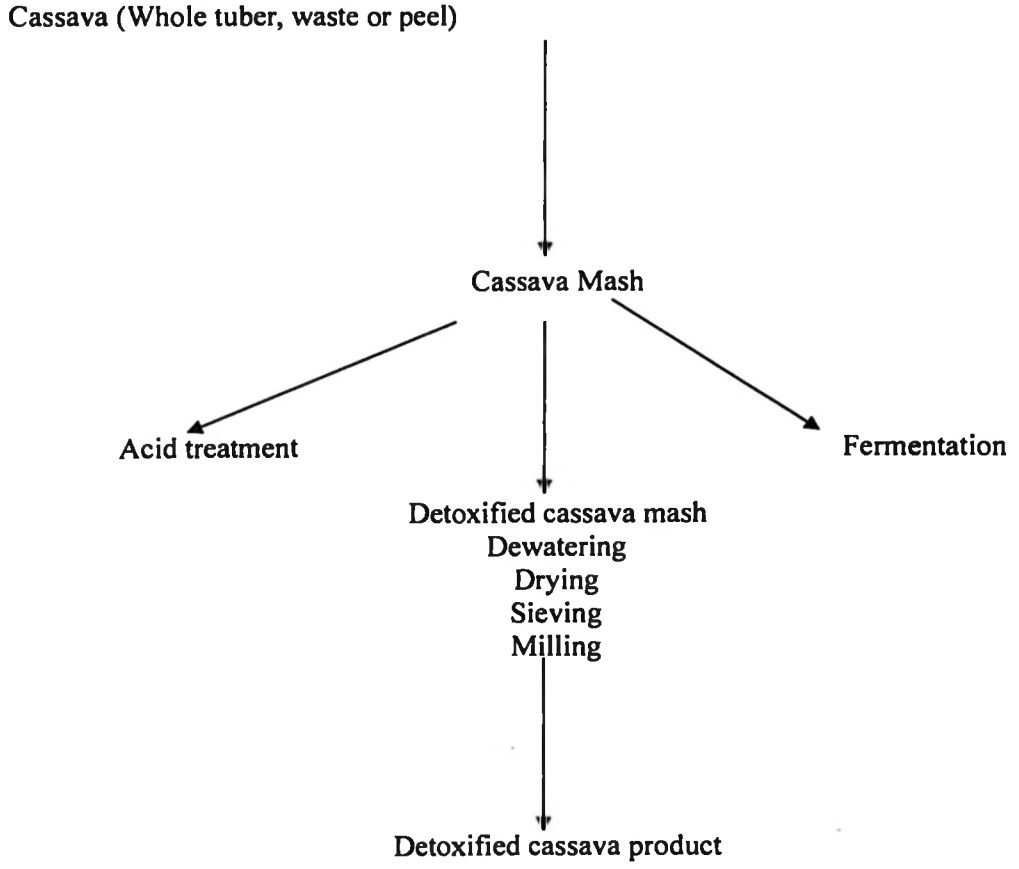

Figure 2: Flow chart for mechanized detoxification processes of cassava for feeds

Source: FAO (2000)

Table 4: pH and Hydrogen cyanide contents during detoxification of cassava

Cassava Material	Unpeeled tuber		Cassava peel		Cassava waste	
	HCN(ppm)	pH	HCN(ppm)	pH	HCN(ppm)	pH
Untreated	156.0	6.03	180.0	5.37	130.0	5.54
After 24 hours	83.20	5.25	52.50	3.91	75.00	3.75
Final product	18.98	nd	18.4	nd	20.80	nd
% loss HCN	87.84	nd	89.7	nd	84.00	nd
After 24 hours	83.30	4.17	52.5	3.78	76.50	3.80
After acid Hydrolysis	15.60	4.10	14.30	4.08	12.20	4.20
Final product	7.80	nd	9.10	nd	10.40	nd
% loss HCN	95.00	nd	95.00	nd	92.00	nd
Untreated	156.00	6.03	180.00	5.37	143.00	5.83
After acid Hydrolysis	6.50	4.04	7.00	4.30	7.80	4.70
Final product	3.00	nd	4.00	nd	4.68	nd
% loss HCN	98.00	nd	97.73	nd	96.73	nd

Source: FAO (2000)

Note: nd = not determined

The dewatered cassava cake is granulated with a hammer mill to an appropriate particle size that will facilitate heat transfer during drying. The wet detoxified cassava granules are fed into a drier of the tray, the fluidized-bed, or the rotary type and dried to a low moisture content to make it shelf-stable. The close relationship composition between cassava and maize makes it possible to substitute cassava for maize in the production of livestock and poultry feeds as an energy and carbohydrate source. The leaves of cassava, especially in the dried forms, can be incorporated into the ration for pigs, poultry and dairy cattle.

2.10 Cyanide metabolism in humans

If cyanogens are not effectively removed during processing, the consumption of cassava may result in dietary cyanide exposure. The source of dietary cyanide from cassava may be ingested glucosides or cyanohydrins, which in the gut may be broken down to hydrogen cyanide. There are several sources of cyanide exposure to humans beside consumption of

insufficiently processed cassava. This includes consumption of other cyanogenic plants such as linseeds or bitter almonds. Fire gases from combustion of nitrogen containing materials and tobacco smoke may also result in cyanide exposure. Other sources are the occupational exposures from alkyl-cyanides used as solvents or cyanide salts used industrially for metal cleaning and polishing. The anti-hypertensive drug sodium nitroprusside consists of 44% cyanide, which is liberated following its administration (Schultz, 1994).

Human body has two defence mechanisms against cyanide. When cyanide enters the blood stream from either the lungs or the gastro-intestinal tract, it is trapped by the methemoglobin fraction in the red blood cells. This fraction normally constitutes about 1% of all haemoglobin, and it can reversibly bind about 10 mg of HCN as cyanomethaemoglobin (Lundquist, 1989). Cyanide can passively be released according to the law of mass action. The second defence mechanism is the conversion of cyanide to thiocyanate (SCN) catalysed by the enzyme rhodanese, also called thiosulphate sulphur transferase. Rhodanese converts cyanide (CN) to thiocyanate (SCN). The conversion requires a sulphane sulphur substrate. The substrate through different metabolic pathways is provided from dietary sulphur amino acids. Substrate availability is the rate-limiting factor (Lundquist 1992). The detoxification process mainly takes place in the liver and the kidneys. Thiocyanate is mainly found extracelluarly in blood, urine, and saliva and in gastric juice (Ruddell *et al.*, 2001). The thiocyanate ion is a pseudo-halide that is handled as chloride and iodide. It is rapidly filtered by the glomerulus and efficiently reabsorbed by the tubule (Schultz, 1994).

When cyanide exposure rates are greater than the conversion rate and cyanide saturates the methemoglobin pool, acute cyanide intoxication occurs. In this situation cyanide rapidly accumulates in plasma and attacks target organs such as the brain (Lundquist *et al.*, 1985). Fatal toxicity of cyanide is believed to be due to energy failure of cells as cyanide inhibits cytochrome oxidase, the terminal enzyme of the mitochondrial electron transport chain and blocks the oxidative phosphorylation (Pettersen and Cohen 1993).

The central nervous system is considered particularly sensitive to cyanide because of its limited anaerobic metabolism, low energy reserves, high energy demands and respiratory rate. Cyanide seems to act directly on the neuronal energy metabolism (Patel *et al.*, 1992). The non-specific clinical symptoms and signs of acute sub-lethal doses of cyanide are light headedness, headache, drowsiness, tremor and coma. Acute inhalation of 2 mmol (50 mg) HCN can be lethal, while ingestion of 200 mg NaCN or 300 mg KCN can be lethal, which on molar basis is twice as much as the lethal dose when inhaled (Labianca 1979, Ansell and Lewis 1970). Lethal blood levels of cyanide in man are estimated to be 180 μmol/l in whole blood and 20-30 μmol/l in plasma. The rate of endogenous detoxification of cyanide in well-nourished adults is around 1 μg (0.04 μmol/kg per minute). This corresponds to a lethal dose rate in an adult of about 3-4 mmol/-24 hours (Schultz, 1994).

2.11 Health affects attributed to cassava toxicity

Cyanide exposure from cassava has been associated with several health disorders in humans. However, due to the methodological limitations of the few studies done, the causal relationship is not fully established between cyanide exposure and the conditions mentioned below (Rosling, 1994).

Acute poisoning following cassava meals is rare in relation to the extensive use of cassava as human food. The published reports are very scarce, especially for fatal poisonings (Akintonwa *et al.*, 1992).

2.11.1 Aggravation of Iodine Deficiency Disorders (IDD)

Cyanide exposure from cassava has been associated to increased goitre frequency, the main manifestation of IDD. This effect has been attributed to increased thiocyanate levels, the end product of cyanide detoxification in the human body. Thiocyanate has been shown to competitively interfere with iodine uptake in the thyroid gland in experimental studies done. The anti-thyroidal effect of thiocyanate has been explained by the pseudo-halide character of the ion which interferes with iodine transport and inhibition of the oxidation of the iodine and by inhibiting iodination of tyrosine in the follicle (Virion, 2000). Field surveys in Zaire suggest that high SCN loads in cassava-eating populations may aggravate the effect of iodine deficiency through a similar mechanism (Bourdoux *et al.*, 1988). However, it has been shown that populations with very high SCN load from insufficiently processed cassava do not develop goiter if iodine intake is adequate (Cliff *et al.*, 1986).

Tropical ataxic neuropathy (TAN) is a neurological syndrome in adults that is characterized by insidious onset of progressive symmetrical peripheral neuropathy combined with signs of myelopathy and sometimes-optic neuropathy. The disease was extensively studied in some rural populations in Nigeria. Osuntokun (1991), found an association between occurrence of TAN and several years of moderate dietary cyanide exposure from cassava and a low protein intake resulting in deficiency of sulphur needed for cyanide detoxification.

Cyanide has been proposed as a causal factor but other dietary deficiencies were also believed to contribute to the disease (Osontokun, 1991). The same syndrome was also reported from Tanzania (Makene and Wilson 2001, Van Heijst *et al.*, 1994). Visual impairment was for the first time attributed to cassava in the last century by the anthropologist Kingsley (1995), who reported that a population in West Africa suffered from blindness attributed to a diet that was too exclusively 'maniocan'.

2.11.2 Konzo disease

Konzo is another neurological disease that has also been attributed to cyanide exposure from cassava. It is a form of spastic paralysis affecting both legs with an abrupt onset and a non-progressive course. The paralysis varies in severity but always mostly affects the distal parts of the legs. Konzo was recently identified as a distinct disease entity (Howlett *et al.*, 1990) and it was named after the local designation among the population in Zaire. In the last decade epidemics of Konzo have occurred in Mozambique, Zaire and Central African Republic, where several studies revealed a consistent association with high cyanide and low sulphur intake from diet dominated by insufficiently processed bitter cassava (Ministry of Health, 1984; Cliff *et al.*, 1986; Essers *et al.*, 1992; Tylleskar *et al.*, 1992; 1994). The neuro-damage was attributed to the combined metabolic effect of high cyanide exposure and low sulphur intake.

2.11.3 Other diseases

Malnutrition-related diabetes is another disease of which cyanide exposure was thought to be an aetological factor. A causal role of dietary cyanide exposure was proposed as a possible cause by animal experiments but epidemiological studies have failed to support a relationship in humans between cyanide exposure and diabetes (Swai *et al.*, 1992).

Protein malnutrition is believed to be aggravated by cyanide intake in children consuming insufficiently processed cassava. The reason is that the limited intake of essential sulphur amino acids in the diet is used for conversion of CN to SCN instead of protein synthesis (Vis *et al.*, 1992).

2.12 Cassava and cyanide exposure in Tanzania

Tanzania is the third largest producer of cassava in Africa (CIAT, 1993) but cassava is only an important staple in half of the country's twenty regions. The most common processing methods are direct sun drying of peeled roots for weeks into a storable product known as makopa. Another method is fermentation of peeled roots by soaking in water for several days followed by sun drying. A third method is fermentation of peeled root pieces in covered heaps to enhance mould growth. The different dried products obtained can be stored and subsequently milled or pounded into flour used for making the stiff porridge, ugali. The processing methods used in Tanzania have only been briefly documented in some of the cassava-growing communities (Sennappa and Mlingi, 2001). They have not been studied in detail in any of the cassava-growing regions. High cyanide exposure from cassava was implicated as the main cause of an outbreak of the paralytic disease konzo in northern Tanzania (CIAT, 1993).

2.13 New method to reduce cyanide in cassava flour

The cyanide contents of ten samples of cassava flour mixed with water (about 1 part flour to 1.25 parts of water) and allowed to stand for about 5 hours at 30°C was reduced to about one third of their previous value. The water added swelled the flour and allowed the enzyme linamarase to catalyse breakdown of the cyanide compound linamarin, with liberation of hydrogen cyanide gas. If there is no linamarase present in the flour then no

reaction can occur and there is no loss of cyanide, but if linamarase is added then reaction occurs (Bradbury, 2006). A very recent study in Mozambique with 30 samples of flour from Mogincual District of Nampula Province has shown an average retention of only 1/6th of the cyanide originally present in the flour. The flour is thoroughly mixed with water added slowly until the volume of the wet flour is about the same as the volume of the flour before wetting. The flour is spread out in a thin (1 cm thick) layer on a tray in the shade for about 5 hours, to allow hydrogen cyanide gas to escape. It is then used the same evening for cooking. (Cumbana *et al.*, 2006). Trials are in progress to see whether this new method is acceptable to the people of Northern Mozambique whose staple food is cassava, consumed mainly as flour. If it is acceptable, and is adopted by the people, it would greatly reduce the intake of cyanide and may lead to the elimination of *konzo* from Mozambique and other countries of Southern, Eastern and Central Africa.

2.14 Cassava processing

Fresh cassava root consists of 60 to 70% water and has a shelf life of 2 to 3 days. Once harvested, it has to be either consumed immediately or processed into more stable product forms. Processing it into dry form reduces the moisture content and converts it into a more durable and stable product with less volume, which makes it easier for transportation. Processing is also necessary to eliminate or reduce the level of hydrocyannic acid (HCN) or cyanide in the crop and to improve the palatability of the food products. Processed cassava products are also used as raw materials for a number of small- or medium-scale industries in Africa. The objectives of cassava processing are to reduce post harvest losses of fresh tubers, eliminate or reduce the cyanide content, improve the taste of cassava products and provide raw materials for cassava-based industries (Nweke, 1994).

2.14.1 Traditional methods for processing cassava

Traditional cassava processing methods under use in Africa probably originated from tropical America, particularly northeastern Brazil and may have been adapted from indigenous techniques for processing yams (Jones, 2003). The processing methods include peeling, boiling, steaming, slicing, grating, soaking or seeping, fermenting, pounding, roasting, pressing, drying, and milling. These traditional methods give low product yields, which are also of low quality (Lancaster *et al.*, 1992).

Table 5: Traditional processing of cassava root

Area / Country	Processing Method	Food Product
Africa (Ghana, Tanzania, Uganda, Zaire)	sun dried, ground	flour, kokonte, cossette, unga, chinyanga, makopa, kivunde, udilimbe, malwa
Africa (Ghana, Cameroon, Nigeria)	soaked, boiled, pounded	water-fufu, paste (dumpling) akpu, agbalima
Africa (Cameroon, Cote d'Ivoire, Nigeria, Zaire)	grated, fermented	baton de manioc, bobolo chikwangue, mboung, placali
Africa (Ghana)		ampesi
Africa (Liberia)	boiled, steamed	depa
India	dried, slurried	incorporated in curry
Indonesia, Nigeria	boiled soaked, shredded, dried	oyek, abacha
Indonesia	steamed, dried	kripik
Latin America	grated, washed	cassareep, beer, dumplings
Latin America	starch extraction	tapioca pudding, sipipa
Latin America (Brazil) Africa (west and central)	crushed, fermented, fried/baked	polvilho azedo, gari, attieke
L. America, Africa (Liberia, Nigeria)	fermented, baked or dried	farinha, Lafun
Philipines	grated, winnowed	cassava rice (landang)
South Pacific (Solomon Islands)	grated (with banana) soaked	pudding
South Pacific(Tikopia)		manioka

Sources: Dixon, 1989; Lancaster *et al.*, 1992.

Rapid urbanization in tropical Africa increased mobility in both rural and urban areas and the changing roles and status of women have resulted in an unprecedented demand for convenience foods. Added to these factors is the high cost of fuel for cooking in urban areas at a time when fuel wood is not only inconvenient to use but is becoming

increasingly scarce. Therefore, cassava processing and utilization technologies for the future should improve traditional methods and develop low cost equipment with low energy demands. Improved processing and utilization technologies should address issues related to farmers' (producers') and consumers' needs (particularly urban needs in future), and also to economic factors and nutritional values. Knowledge of the current traditional processing and utilization methods and of present urban patterns of consumption and changing urban needs will guide future strategies for cassava processing and utilization.

Improvement of nutritional values of processed products also requires special attention from policy makers and researchers. Cassava is frequently denigrated because its roots are low in protein. However, protein may be supplemented from other sources, particularly legumes; for example, fortification of cassava flour or gari with protein-rich soyflour can be achieved. Such fortified products will be nutritionally advantageous, and thus economical and acceptable to consumers (Nweke, 1994).

Although cassava is regarded as subsistence crop of low-income families or as a "famine-reserve crop", about 60 percent of the cassava output of households in the Oyo area of Nigeria is sold for processing (mostly into gari) while the remaining 40 percent is consumed at home. A high proportion (50 percent) of cassava was also sold to food processors in the western region of Cameroon (Okezie *et al.*, 2003), suggesting a changing status for cassava.

2.15 Technologies available worldwide

The technologies available world wide for processing of cassava involve those for the production of chips, pellets, native starch, modified starch/adhesives, alcohol (ethanol),

Monosodium glutamate (MSG), citric acid, sweeteners e.g. glucose, fructose and sorbitol. In addition, the use of cassava for the production of foods in Africa, such as gari, fufu, instant flour, fermented flour, and other products exist. The processing of cassava leaves for the production of hay (animal feed), as well as for leaf protein concentrates are gaining grounds (Lundquist, 1992).

2.16 Modern cassava processing technologies

2.16.1 Chip production

Chip production involves the simple technique of cutting peeled or unpeeled cassava roots into smaller pieces and allowing the pieces to dry. Sun drying is the most common technique, while different types of chipping machines or choppers are used.

2.16.2 Pellet production

Pellet production was stimulated by the need to improve the uniformity in the shape and size of cassava chips required by the users and animal feed producers. In addition, during transportation, loading and unloading of chips, dust generation caused serious air pollution, placing pressure on the importers in Europe to improve the nature of cassava products handled by the ports. Production of pellets involves pressing chips and extrusion through a large die. The heat and moisture in the chips help in the formation of pellet-like shaped product known as soft pellets. Later process developments involved grinding of chips followed by steam extrusion. This process produces strong pellets upon cooling. These types of pellets are known as hard pellets (Nweke, 1994).

2.17 Cassava starch and flour production

The production of starch and flour from cassava has been an age long process. The technology for starch production involves peeling and washing of the tubers followed by grating or mashing (also called pulverization) and then mixing the resultant mash with water. The suspension is then sieved and the slurry sedimented. Water is decanted and the sedimented starch dried. Different machines are used at the various stages of the process depending on the level of sophistication of production (Sokolov, 2002). Flour production involves peeling and washing the tubers. These are then cut into pieces and dried. The dried pieces are then milled and sieved. The resultant flour in this process is the unfermented flour. The fermented flour is produced by fermenting cassava through soaking or steeping the peeled and cut pieces of cassava in water. The fermented pieces are then dried before milling and sieving. Improved technology in the production of fermented cassava flour has led to the production of odour less fufu and instant flour in Nigeria (IITA, 2002).

2.18 Cassava processing in Tanzania

Cassava leaves are normally sun-dried in the open or may be dried in ashes but this takes a longer time (10-15 days). The resulting hay is then mixed in the diets in the required proportions. In the dried form, cassava leaves can be stored for a long time. Drying the leaves also reduces HCN content. Mngulwi (1993) reported HCN content of 1210 ppm of dry matter for fresh leaves and 30 ppm for dried leaves. It is a common practice to sun-dry the roots when they have been chopped into small pieces. Peeled roots are normally fed to pigs and poultry while unpeeled roots are fed to cattle. The peel is rich in protein, fat and ash. Peeled fresh roots can be fed to pigs and poultry at low levels without any signs of toxicity.

2.18.1 Cassava and cassava flour

Cassava flour is the product obtained from milling the dried, raw tapioca root (FAO, 1998). 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, 2002; DeFloor and Delcour, 1993). 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 tapioca flour (Raja and Ramakrishna, 1990). Although grains are the primary source of flour in food applications such as bread making, pastas and breakfast meals, there is evidence that tapioca flour has been used for breadmaking in the Caribbean for several generations (Sokolov, 2002).

Production of cassava root is geared towards domestic consumption and exportation. Brazil produces about 25 million tons of tapioca roots per year for domestic consumption and export. Nigeria, Indonesia and Thailand also produce large amounts of cassava root for export (CIAT, 1993). Overall production of cassava root in Africa was estimated at 85.2 million tons in 1997, while in Asia, it was 48.6 million tons, and 32.4 million tons in Latin America and the Caribbean (FAO, 1998).

Cassava root has a high resistance to plant disease and high tolerance to extreme stress conditions such as periods of drought and poor soils. Portuguese settlers in Brazil initially spread cultivation of this crop from Brazil to central Africa, and later European settlers promoted its use as an effective defense against famine (FAO, 1998; Lancaster *et al.*, 1992, Kahn, 1989; Jackson and Jackson 1990). Cassava flour is the flour obtained from milling the dried root. A range of processing techniques are employed to produce cassava based

foods and beverages. In addition, it finds use as animal feed, in textiles and as raw material in beer brewing.

2.19 Uses of cassava

Cassava is grown chiefly as human food, but it is also an important animal feed, and it has several significant industrial uses. Apart from the economic activity inherent in cassava growing itself, the processing and marketing of cassava generate employment and provide opportunities for the development of rural industries. Being one of the cheapest sources of food energy, cassava could play a major role in meeting developing countries' rising consumption of both food and animal feed. Cock (2001) continued to explain that cassava can save developing countries from importing cereals, because it can grow well on land that is not suited to cereals and other food crops.

2.19.1 Cassava utilization as human food

Cassava is extensively cultivated throughout the tropics for its starchy roots, which form a primary or secondary staple for many people (Coursey, 2000). The crop is an efficient producer of carbohydrate. It is tolerant to drought, grows fairly well in poor soils with low pH and is relatively resistant to diseases and insect pests. It has no precise maturity, and can be left in the ground and harvested nearly any time of the year, thus being good security against famine (Lancaster *et al.*, 1992).

Cassava's potential yield is greater than for other crops, and production in calories per hectare is higher than any other staple food, while it requires a minimum labour to produce (Meyote, 2004). The consumption patterns of cassava differ among regions. In Africa, nearly all cassava is used for human consumption. In Asia, about half of the cassava is

produced for direct human consumption, and the remainder is exported in form of chips and pellets, while in Latin America, the amount of cassava produced for human food is only about a 40%. More than half of the eaten cassava is processed into forms such as flour, meals and starch (Cock, 2001).

According to Asiedu (1999), fresh peeled cassava is eaten as a vegetable after boiling or roasting. In West African countries, cassava is boiled and pounded with boiled plantain to form elastic dough called fufu, which is consumed with vegetable and meat soups. The roots of the sweetest varieties are sometimes eaten raw as an (in -between-meals) snack or thirst quencher. When cooked, the roots become equivalent to potatoes, but their taste is considerably "heavier'. In Indonesia the roots are often wrapped in leaves after covering them with a yeast preparation, and then fermented to produce a soft and slightly alcoholic side-dish (Meyote, 2004). Peeled cassava roots are also sliced, dried and ground into flour and processed into many different products.

2.19.1.1 Traditional cassava products

Cassava roots are processed into different food products. The products vary from one place to another.

(a) Farinha de Mandioca

This type of food from cassava is popular in Brazil and other parts of South America. Asiedu (1999) explained the preparation of farinha de mandioca, which consists of peeling, grating, pressing, mixing, heating and roasting. After grating or rasping, the cassava pulp is packed into tipiti (a basket-weave tube). The tipiti Plate 2-1, as shown in, is stretched and its internal volume reduces, squeezing juice from the pulp.

During this operation, the pulp is subjected to considerable pressure, causing the juice containing cyanogens to drain off. However, the tipiti is not used in large scale production practiced in factories.

The moist mash from the tipiti is mixed with 3-day old pre-fermented pulp, pounded together and rubbed through a sieve. Then the pulp is roasted in large flat pans. During roasting, the pulp is turned continuously with a wooden rake and results in a granular product. This is then eaten with meat and gravy. On the other hand, when the pulp is heated more intensively, without stirring to form a slightly brown mass, it forms Couac (bread) which is then sun dried and can be stored for a long time.

(b) Gari

Gari is a popular food among the low-income groups in West Africa and Nigeria (Meyote, 2004). It is produced by fermenting grated cassava roots, semi-dextrinizing the pulp by heat and then drying the product. The production of gari is a modification of the process for the manufacture of farinha de mandioca, but it has a characteristic flavour (Cock, 2001). Cassava roots are washed, peeled and grated; the resulting pulp is put into a cloth bag subjected to pressure by heaping stones and logs on the bag. The juice is squeezed out. The bag is left for about 2-4 days, and the pulp undergoes fermentation. This method is not considered to be as effective as the tipiti in squeezing out the juice. Later on the fermented pulp is removed from the bag, sieved and roasted or fried usually with palm oil in shallow metal pans or small pots until dry. The product is then packed into bags and stored.

Cassava bacteria (Corynebacterium manihot) produce lactic acid and formic acid from starch during fermentation, which causes development of the characteristic flavour of gari. When the pH has fallen down to about 4.2, the fungus (Geotricium candida) produces more acid and the characteristic aroma.

(c) Cassava rice (ladang)

Ladang is a popular food in Philippines and some other parts of South East Asia. According to Asiedu (1999), cassava rice is prepared by shredding the roots and pressing the grated pulp in a cloth to remove the juice. The drained mass is whirled in a winnowing basket and forms pellets. The moisture content and the speed of winnowing determine the size of the pellets. Sifting gives pellets of more or less uniform size. They are then steamed or dried. In an alternative way as explained by Meyote (2004) the roots are soaked in water in earthenware jars for five to seven days, until they are soft. Then they are macerated, fibre removed and the mass is air dried and made into pellets.

(d) Kokontse

It is common in West Africa. Doku (1999) explained kokonte preparation, whereby cassava roots are peeled, cut into pieces and dried in the sun, usually on roofs or along the road side. The dried roots (kokonte) are milled into flour. The flour is usually cooked by adding it to boiling water, and stirring until the correct consistency is obtained (sticky porridge).

(e) Chikwangue

It is an African type of food. Cassava roots are soaked in water for several days until they become soft, then the roots are peeled and macerated. The fibres are removed and the dough formed is wrapped in banana leaves and boiled (Meyote, 2004).

(f) Tapioca

This is obtained when starch is allowed to settle from the juice pressed out from the grated cassava pulp. The supernatant juice is decanted and the starch is washed, dried and roasted in a pan with continuous stirring like gar, but using low fire. The starch grains burst open and partial dextrinization of starch causes particles to adhere to form larger granules of various sizes (Doku, 1999).

(g) Fufu

Fufu is common in Sierra Leone. During its preparation, cassava roots are washed, peeled, grated, sieved and allowed to stand for sometime, but the juice is not squeezed out. Fermentation takes place and at this stage, after which the juice is drained off. The resulting dough is stored and used to prepare fufu by putting some dough in a pot of boiling water and stirring continuously to produce a sticky meal (De Bruijin *et al.*, 1991).

(h) Yake yake

This is also common in West Africa. Its preparation involves peeling, washing and grating of cassava roots. The pulp is dried and sieved, then mixed with some salt and moulded into flat small 'cakes', which are steam baked for a few minutes. It is eaten with soup or stew (Fresco, 1982).

(i) Casabe

Casabe is an important cassava food product in the Caribbean islands and on the Atlantic coast of Colombia and Venezuela. Cassava is processed in the same way as for the production of farinha, except that the squeezed cassava mash is kneaded into a flat cake and baked (Goosens, 1996).

2.19.1.2 Cassava as animal feed

Cassava is widely used in most tropical areas for feeding pigs, cattle, sheep and poultry. While in Brazil and Paraguay, animals are fed on considerable quantities of fresh cassava roots, in Asia, most cassava is dried before being used as animal feed (Cock, 2001).

Cock (2001) reported that pigs and poultry which were fed on cassava as energy source, even with supplemental proteins, had lower growth rates and feed conversion efficiencies than animals on cereal - based diets. Recently it has been found that methionine, plays a role in the detoxification of cyanogens. With the addition of protein, methionine and adequate levels of vitamins and minerals, low levels of cassava can replace maize in pig and poultry diets with no decrease in performance.

Cassava has become an important animal feed for a long time. A large quantity of cassava chips and pellets are exported to the European Community, mainly from Thailand, Malaysia and Indonesia. Cassava roots are an excellent energy source for ruminants, whether dried or, in case of sweet cassava, fresh (Danforthcentre, 2002).

Meyote (2004) explained that chips are the form in which most dried cassava roots are marketed. These are dried irregular slices of roots, which vary in size but do not exceed 5

cm in length so that they can be stored in silos. Cassava chips processing starts with sorting and washing the roots. They are then shredded by machine, and cut into slices as they pass through the machine. The sliced roots are spread out to dry, where they are turned periodically to enhance drying. Artificial drying may be required in areas with high rainfall.

Cassava can also be found in the form of meal. This is the powdery remains of chips and rots after processing to extract edible starch. The quality of the meal is low compared to chips and pellets. Its starch content is low and it includes a lot of sand (Cock, 2001). But it is still used by some farmers due to its cheapness.

2.19.1.3 Industrial uses

Cassava is also an important raw material in starch production. Starch from different cereals and tubers including cassava, is widely used in the food industries (Cock, 2001). Starch can be used in the form of cooked starch foods, e.g. custard. It can be used as a thickener in soups, baby foods and sauces. This is due to its paste formation properties. Meyote (2004) explained the use of starch as the filler contributing to solid content of soups and ice cream. Starch can also be used as a binder especially in sausages and processed meats. This helps to consolidate the mass and stops it from drying out during cooking. Due to its high water-holding capacity, starch can be used as stabilizer especially in ice cream.

Starch is also used in the manufacture of candies and boiled sweets, in the making gums and pastes, also sprinkled on sweets to prevent them from sticking together. It is widely

used in the manufacture of monosodium glutamate (MSG) in Far East and Latin America countries.

On fermentation by yeast, starch produces alcohol. Cassava contains 30% starch and 5% sugars. When dried, the roots have approximately 80% fermentable substances. Roots are washed, crushed into thin pulp and screened. In alcohol production, Sulphuric acid is added to the pulp to allow saccharification, when total reducing sugars reach 15-17% of the content, Fermentation by yeast is allowed to take place for about three to four days. Sodium carbonate is used to adjust the pH. Distillation is carried out to separate the alcohol. A ton of cassava can produce between 70-110 litres of absolute alcohol. This alcohol is mainly used for industrial purposes such as in cosmetics and solvents (Meyote, 2004).

2.19.2 Non food uses

Starch is widely used in the textile industry for sizing, cloth finishing and printing. In the paper industry, starch is used mainly to improve the finishing, appearance, strength and printing properties. It also makes papers resistant to scuffing and folding (Whistler and Paschall, 1993). According to Meyote (2004) cassava starch is used as a natural adhesive. It can be in the form of a roll-dried adhesive or a liquid adhesive. Starch is converted to dextrins by using chemicals, as well as enzymes. Cassava dextrins are preferred in remoistening gums for stamps and envelope flaps. It has good adhesive properties and acceptable taste and odour (Knipfel, 1975).

Dextrins are mainly used in the corrugated cardboard industry for the manufacture of cartons, boxes and various packaging materials (Kweon *et al.*, 1994). Starch-based

products are used as adhesives for wallpaper and for various domestic uses. Again, starch is very useful in coating and binding sand grains, which are used in moulds in the manufacture of castings for metals.

2.19.4 Potential applications of cassava flour

Traditionally, cassava bread is baked by toasting cassava root pulp on a griddle and is known as cassava bread, *casabe, beigu* or *couac* in the Caribbean (FAO, 1998). However, other kinds of cassava flour bread are being made now with the inclusion of composite flour such as soybean and peanut flour. Composites, with high protein flour such as soybean flour and wheat bran have been shown to improve extrusion properties and functionality of tapioca flour (Badrie and Mellowes, 1992). Cassava flour is popular in the food industry due to its special characteristics - clarity of appearance, low flavor overtones and ideal viscosity. It has been tested as filler in comminuted meat products (Annor-Frempong *et al.*, 1996). With the expansion of the food industry and increase in nutritional needs of the cassava - consuming populations, cassava flour and cassava starch are just being examined for optimization and greater utilization. Some newly tested applications of cassava flour in recent years have been as weaning foods, as substrates in alcohol production and for glucose syrup production (Adewusi *et al.*, 1992; Vuilleumier, 1993; Pontoh and Low, 1995).

2.20 Improvement of roots keeping quality

Cassava roots are processed because they are extremely perishable (Cock, 2001). Within two days of harvesting, cassava deterioration starts. This posthavest deterioration of cassava involves two separate processes. It starts with internal discoloration, which spreads along the vascular system from wounds, then after a few days, microbial rotting

follows (Booth and Wholey, 1976; Rickard and Coursey, 1981). The initial type of deterioration known as physiological (or primary) deterioration, starts within 24 hours after harvest, and is characterised by fine blue-black or brownish discoloration, (Vascular streakings) observed in cut or in damaged areas in the roots (Meyote, 2004). Then follows microbial (secondary) deterioration, which usually starts within a week after harvest. This is characterised by brown streaks throughout the fleshy part of the root and soft spots (Cock, 2001).

Lundquist (1992), investigated the effect of storage environment on development of physiological deterioration, and observed that discoloration does not penetrate into the roots, when water loss from the cuts of periderm injury is suppressed. Meyote (2004) suggested that wound healing or curing which occurs during storage at high temperature and high humidity, can prevent physiological deterioration.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the study area

Newala district is located at the middle of Mtwara region in southern Tanzania. Average annual precipitation is 940mm and temperatures vary from 18° C low in July and 36° C high in December. Cassava is the primary staple food in Newala District. Newala district is administratively subdivided into 6 divisions, 38 wards and 233 villages and the 1948 and 1967 censuses indicated that majority of the indigenous people of the District were of Bantu origin mainly Makonde (NBS, 2003). According to the population census of 2002 (NBS, 2003) Newala District has a population of 83 344 people with 49 726 households with average size of 4 people per household. More than 80% of the total population lives in rural areas.

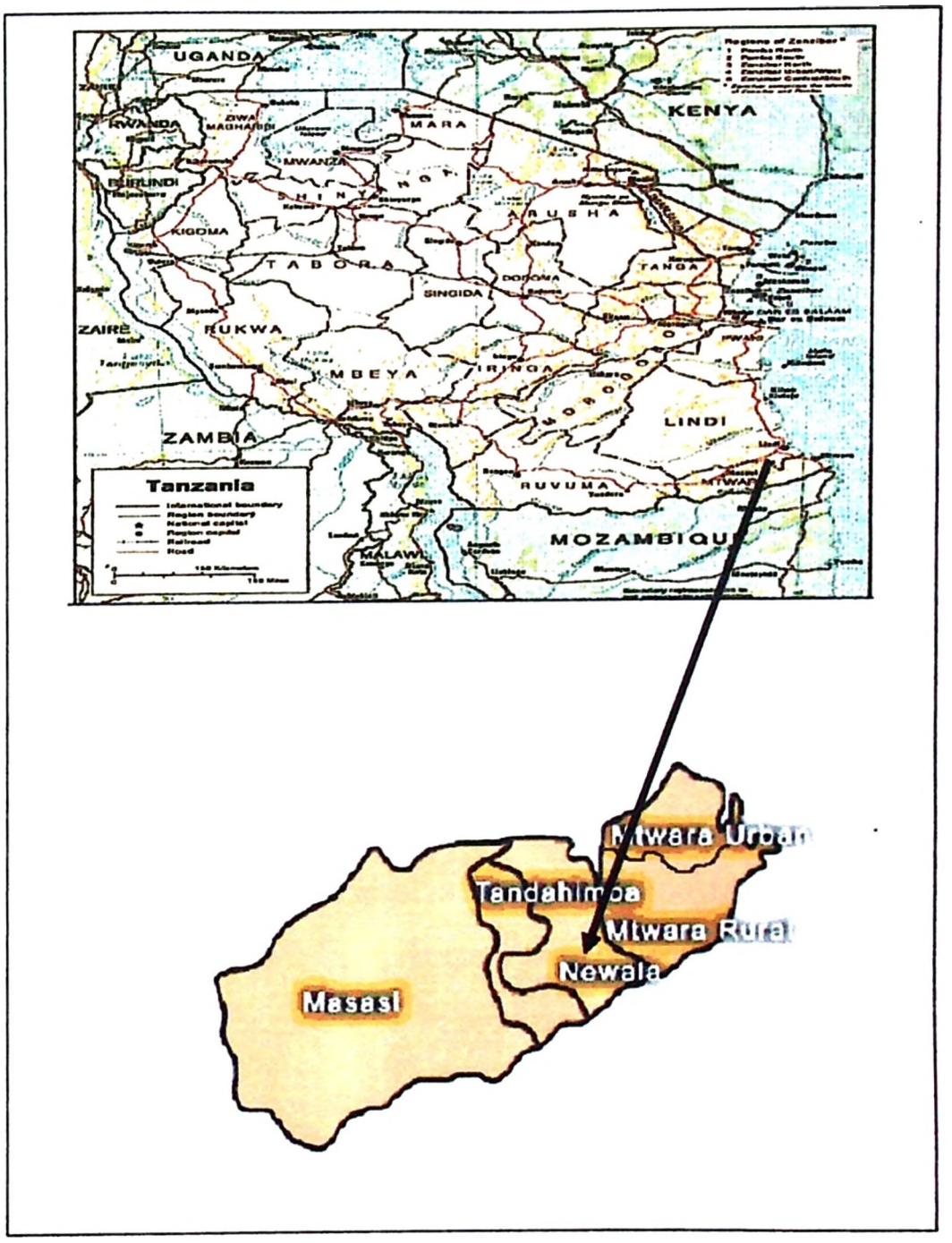

Figure 3: Location of Mtwara region

Source: NBS, 2003

3.2 Study design

The study involved mainly two methods: Field survey and laboratory analyses.

3.2.1 Field survey

The field survey was conducted to assess and obtain information on different local cassava processing methods practiced, the cassava cultivation, utilization and social economic factors, which affect cassava production, processing and utilization in Newala district. District authorities were asked to select villages in different parts of the district that were known to have high cultivation of bitter cassava varieties and that reported cases of acute intoxications from consumption of insufficiently processed cassava in the previous years. Quantitative data collection using structured questionnaires and focus group discussion with village leaders, elders and women were used. The data that were collected in this design were used for simple descriptive interpretations. Three villages were selected using purposive sampling method based on high consumption of cassava and presence of high acute intoxication from cassava consumption. In each selected area (village) 40 households were interviewed (with average of 4 people) one sample of cassava root and flour was collected from respondent of each household interviewed for analysis of cyanide and major nutrients retention.

3.3 Data collection

Both primary and secondary data were collected. Primary data were collected through focus group interview with key informants (leaders, elders and extension officers) and interview from each household with a questionnaire with open and close ended questions. Secondary data were collected from local authorities, other key informants Sokoine University Library and Internet source.

3.4 Sample size

Proportionate stratified sample were employed with the sample size of 120 respondents. In the randomly selected sampling areas the following information were gathered:

(i) The knowledge and attitude of people towards cassava processing and utilization were assessed.

(ii) The processing methods used were assessed and documented.

(iii) Cassava processing constraints and health related problems associated to consumption of poorly processed cassava were assessed and documented.

(iv) The quality of processed cassava was assessed and documented.

3.5 Cassava samples collection and analysis

Makopa samples analysed in this study were collected from three villages in Newala district: Songambele, Malatu and Mtangalanga depending on the type of processing practiced. All samples were pounded into flour. Samples of dry cassava products were collected from each sampling area aseptically, packed in sealed polyethylene bag and brought to SUA and TFNC laboratories for analysis of nutrient and cyanogenic glucosides residues.

3.6 Residual cyanide residues determination

Determination of cyanogen levels in extracts of cassava samples collected from the households was made according to the method described by O'Brien *et al.* (1992).

3.6.1 Cyanogens determination by enzymatic assay

By this method, cyanide (HCN), cyanohydrins, and glucosides were determined. For free cyanide (HCN), 3.9 ml of pH 4.0 phosphate buffer were added into test tube, followed by

0.1 ml of extract. Then, 0.2 ml of chloramines T. The tubes were kept in an ice/water bath for five minutes then pyridine reagent added. At this stage the colour development changed from pink to blue and tubes were kept in a fume cupboard for 90 minutes, then spectrophotometer readings taken at 620 nm. For the cyanohydrins and glucosides, 0.1 ml extract was added to 0.4 ml pH 4.0 phosphates buffer in the test tube. This was followed by 0.6 ml of sodium hydroxide (0.2 M), and then 2.9 ml of pH 4.0 phosphate buffer were added. Next the colorimetric procedure was followed.

Total cyanogens were determined as follows, 0.4ml of pH 7.0 phosphate buffer being added into test tubes followed by 0.1 ml of an extract. In this case linamarase enzyme was added, (0.1ml) and incubated in water bath at 30C for 15 minutes. (The enzyme was added at the interval of 20 seconds). Then 0.6ml of sodium hydroxide (0.2M) was added (at the interval of 20 seconds exactly, to make sure all the tubes had the same incubation time of 15 minutes). Next, 2.8 ml of pH 6.0 phosphate buffer was added followed by the colorimetric procedure. The blanks in all were prepared in the same way as samples, except that 0.1 ml of extracting medium was used instead of extract.

3.6.2 Calculation of cyanogens content in extracts

According to by O'Brien *et al.* (1992) the cyanogens content of an extract of cassava is derived as follows:

$$CC = \left(\frac{10V \times A}{(Equivalent\ A_{620}\ 1\mu g\ HCN) \times X} \right) \mu g\ HCN / g\ Cassava$$

Where:

CC = cyanide content

V = volume of extract obtained after filtration/ centrifugation (ml)

A = mean A_{620} from extract

X = weight (dry) of sample from which extract was made (g).

More recently this equation has undergone some modifications. Firstly, as a result of investigation at ODNRI, involving the incorporation of exogenous acetone cyanohydrin in Nigeria gari (a fermented, cooked, cassava food), it is indicated that, the cyanogens content of the recovered extract is equal to the portion retained by the cassava homogenate. Secondly, it is thought that the moisture from the cassava sample itself will dilute the extract during sample homogenization. In that case the moisture content of the sample should be taken into account, when considering the volume of extract. These adjustments give rise to a new equation, which is:

$$CC = \left(\frac{10V^{1} \times A}{(Equivalent\ A_{620}\ 1\mu g\ HCN) \times Xd} \right) \mu g\ HCN / g\ Cassava$$

Where:

CC = cyanide content

A = mean A_{620} from extract

Xd = dry weight of sample from which extract made (g)

V^{1} = adjusted volume as:

$$V^{1} = \frac{V + (Xfx\%H_2O)}{100}$$

Where:

V = volume of extraction medium used (ml)

Xf = fresh weight of sample from which extract made (g)

3.8 Proximate analysis

Different nutrients were determined (Protein, Starch, moisture content, vitamin C and pH) from processed cassava by using AOAC Methods for the estimation of their nutrient quality.

3.8.1 Crude protein determination

Crude protein of cassava flour samples was determined using the semi micro Kjeldahl's method as described in the AOAC method No.920.152 (AOAC, 1972). About 0.5g of cassava flour samples were weighed in triplicate and digested.

Hence, the computation for the total N and crude protein in the sweet potato samples were worked out as follows:

$$\%N = \left(\frac{(14 \times 0.1) \times A}{W} \right) \times 100$$

Where;

A = the titre of acid used in milliliters

W = original weight of the digested sample

%Crude protein = %N x Factor (6.25)

3.8.2 Determination of moisture content

The moisture content of sweet potato samples was determined in triplicate samples following the AOAC method No. 925.10 (AOAC, 1972). Whereby the cassava flour samples were dried at 105° C overnight. The weight of each sample was recorded for each triplicate. The average was worked out so as to establish the percent moisture content.

$$\%\,Moisture = \left(\frac{(W_2 - W_1) - (W_3 - W_1)}{(W_2 - W_1)} \right) \times 100$$

i.e. $$\%\,Moisture = \left(\frac{Loss\ in\ weight\ after\ drying}{Initial\ weight\ of\ sample} \right) \times 100$$

3.8.3 Cassava starch extraction

Starch was extracted from chopped cassava roots using waring blender, passing the slurry through a 55 μm sieve and allowing the starch to sediment overnight. Settled starch was dried in an oven at 40°C for 72 hours, turning occasionally at the first stages of drying. Emulsifiers were added to cassava starch and mash (2%). In the case of starch some water was added to form a suspension. Cassava starch suspensions and cassava mash were dried in an air draft assisted oven at 50°C for 8 hours to allow starch emulsifier complex formation to form suspensions (1:3 starch-water ratio), (Moorthy *et al.*, 1996).

3.9 Statistical analysis

Quantitative data from respondents were verified, compiled, summarized and presented using percentages. For the laboratory data, the raw data was subjected to ANOVA for identifying their mean levels of cyanogenic glucosides significances from the samples.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

This chapter represents results and discussion for the data obtained from the formal and informal survey and Laboratory analysis. The results are divided into three sections; the first section present descriptive statistics showing characteristics of sampled cassava growers. This is followed by results and discussion of cassava production and processing constraints. Lastly the chapter addresses the results and discussion from proximate analysis.

4.1.1 Social economic variables

4.1.1.1 Age of respondents

The age of the respondents ranged from 20 years to a maximum of 80 years. About 54.5 percent of the respondents were above 50 years, 37.2 percent between 36 and 50 years and 8.3 percent were between 20 and 35 years as indicated in Table 6 below. The large percentage of the respondents above the age of 50 years was due to the fact that old people are the ones who own resources. Youth either migrate to urban areas or engage in off-farm activities.

Table 6: Age of respondents (n=120)

Age	Percentage
Above 50 years	54.5
Between 36 and 50	37.2
Between 20 and 35	83.0

4.2.2 Marital status

From Table 7, about 81.4 percent of the respondents were married. This shows that the society is stable; A stable family can concentrate more on production than unstable one thus may influence agricultural production. Divorce rate was low at only 0.8 percent. Where as only 4.2 of the respondents were single. Goosens (1996) reported that, ability of a family to engage in agricultural production depends mostly on its stability because the stable family under the control of father and mother can easily accomplish its duties than unstable one.

Table 7: Marital status of respondents (n=120)

Marital Status	Frequency	Percent
Married	107	89.2
Widowed	7	5.8
Single	5	4.2
Divorced	1	0.8
Total	**120**	**100.0**

4.2.3 Education level

Table 8 presents the frequency and percentages of sample cassava growers against their education levels. The majority of the respondents (83.3%) reported to have formal education whereby 67.2% had primary education and 16.1% secondary education. Only 2.5 percent attended adult education classes while 4.2% attained standard four of primary education. Amani (1996) asserts that under ceteris paribus, educated household members tend to be more productive in agriculture and likely to have more off-farms incomes and opportunities than non-educated households members.

Table 8: Education level of respondents (n=120)

Level of Education	Frequency	Percent
Adult education	3	2.5
Primary education	80	67.2
Secondary education	19	16.1
Others	5	4.2
Total	**120**	**100.0**

4.2.4 Major source of income

Table 9 shows activities providing major sources of income to cassava farmers. It is clear that 90.8 percent of the respondents' major source of income is farming. The remaining percentage is accounted for by respondents whose major source of income is from livestock keeping (7.5%) and from informal sector (1.7%) that include; carpentry and local beer making. Like in many other districts of Tanzania, agriculture is the major economic activity (Rwiza *et al.*, 1995).

Table 9: Major sources of income (n=120)

Sources of income	Frequency	Percent
Farming	109	90.8
Livestock	9	7.5
Informal sector	2	1.7
Total	**120**	**100.0**

4.3 Socio-cultural issues-gender, HIV/AIDS and environment

Apart from poor or lack of production and processing technologies, and poor marketing infrastructure, a number of crosscutting constraints to cassava development were observed during field visits in all the three villages visited. There was a lack of organization of the farmers into working groups that could enhance their productivity and bargaining power,

including gender mainstreaming. There was also lack of domestic financing programs for small-scale producers and processors of cassava. A number of specific socio-cultural issues were noted: This implies that it is difficult for them to get credit, entrepreneurship skills and technology promotion from financial institutions, these findings have also been reported by Goosens (2002).

The HIV/AIDS epidemic was also found to have contributed to the non-availability of family labour in some villages, especially those of Songambele and Malatu. This was found to be a challenge that calls for direct support in terms of domestic financing programs for small-scale producers of cassava i.e. some form of credit to be advanced to the small farmers to be able to hire labour in order to increase their productivity. It was, however, noteworthy that all villages in the district have HIV/AIDS programmes and the farmers were aware of the epidemic. There were NGOs implementing Gender/HIV programmes in the district namely Care Tanzania, AMREF, and Plan international.

4.4 Land holding, usage and inheritance patterns

In all villages visited, access to land for production, was not gender biased. Either of the sexes could get involved in cassava development. There was no bias when it came to providing access to farmland for women. Like wise, there were no important cultural belief practices that were likely to affect the development of cassava.

4.5 Accessibility to free family labour

Results from Table 10 shows that 35.8% of the respondents stated that accessibility to free family labour was low, 15% it was high and 49.2% had no accessibility to free family labour. This showed that access to free family labour was a big constraint in the study area.

Table 10: Respondents accessibility to free family labour (n = 120)

Accessibility to free family labour	Frequency	Percentage
Low accessibility to free family labour	43	35.8
High accessibility to free family labour	18	15.0
No accessibility to free family labour	59	49.2
Total	**120**	**100.0**

Extension officers and village leaders revealed that many young adults and primary school leavers who were economically active group have migrated to town in search of "better life", leaving children and older people in rural areas. As a result, family labour to cultivate and weed the family farms was not adequate. Although during peak seasons for cultivation or weeding, hired labour was normally available in the villages; the farmers could hardly afford to pay them. This was even worse for widows and women heads of the household.

4.6 Local processing methods practiced in the study area

Results form Table 11 shows that, about 73.3% of the total respondents stated that they used sundrying only in cassava processing, while 16.7% stated that they used both sundrying and wet fermentation. However, fermentation depended on the availability of water. Ten percent of the total respondents revealed that they used wet fermentation for cassava processing.

Table 11: Local processing methods practiced in the study area (n = 120)

Processing methods	Frequency	Percentage
Sun-drying only	88	73.3
Sun-drying and wet fermentation	20	16.7
Wet fermentation	12	10.0
Total	**120**	**100.0**

These results imply that sundrying was mostly practiced as cassava processing method in the study area. Mlingi (1992) reported that the cassava processing method most practiced in the southern part of Tanzania was sundrying.

4.7 Production, on-farm processing and consumption

4.7.1 Production

Extension officers revealed that cassava production in the study area was done locally by capital inputs such as; hoe, machete, axe, etc and land was cleared using the slash and burn method. The production of cassava in the target villages of Newalla district ranged between 1.5 and 35 tons per hectare. Also the extension officers stated that, cassava was a major staple food crop in Newala District. It plays an important role in food security as well as a source of income to the people who cultivate process and market it in rural and urban areas. Cassava leaves were important leafy vegetables in the Newala district, and were available throughout the year. The leaves are good source of protein, minerals and vitamins and also as a source of cash to producers who sell leaves.

4.7.1.1 Varieties of cassava grown

The interviewed households revealed that the prolonged drought seasons in the recent years caused the most severe food shortage period ever experienced in the district. Also the interviewees reveled that many families grew both bitter and sweet cassava varieties, but during drought season all roots from both types tasted bitter.

Table 12: Varieties of cassava grown (30 households)

Cassava varieties	Frequency	Percentage
Bitter variety	84	70.0
Sweet variety	16	30.0
Total	**120**	**100.0**

From Table 12 above, among the 120 respondents interviewed, 70% cultivated only bitter varieties, while the remaining cultivated both bitter and sweet varieties. It is reported that the concentration of the glycosides varies considerably between varieties and also with climatic and cultural conditions and cassava is classified as "bitter" or "sweet" according to the amount of cyanide present (Bolhuis, 1996). During dry season there is high concentration of thiocyanate (cyanide metabolite) indicating low intake of sulphur amino-acids which provide a substrate for cyanide detoxification, thus the cassava tastes bitter while in wet season the concentration of thiocyanate dropped to almost half of the dry season values (Tylleskar *et al.*, 1992).

4.7.1.2 Cassava production constraints

Extension officers and village leaders revealed that farmers from the study area faces a lot of production constraints. These included low knowledge level among rural people and the high traditional attitudes and actions growing out of illiteracy and poor education. It is a traditional belief that soil fertility comes from the ancestors, and to receive it, the farmer has to respect the traditional agricultural practices. Another constraint was inadequate farm inputs necessary to support the desired technological evolution, such as improved seeds, fertilizer, and pesticides. Reported also, lack of adequate labour force caused by the economically active working group usually migrating to urban areas to seek jobs whilst leaving the less active working people in their villages. Fresco (1986) reported that, the

farming system responded to the demand for cassava only by using more labour and adequate agricultural inputs. A growing number of studies suggests that education can enhance the productivity of farmers in developing countries. The most comprehensive of these is that of Jamison and Lau (2001), who reviewed previous work on education and agriculture and analyzed a large data set from Thailand. Although done over 20 years ago, its rigorous methods farm-level production functions, and its clear message education has positive effects on agricultural productivity, keep it relevant to today's discussion. More recently, Alderman *et al.* (1996) conducted a survey in rural labor markets in Pakistan, using the Ravens Matrices as a test of ability, as was done in the earnings functions research reviewed by Glewwe and Paul (2002). They found support for the productivity enhancing role of primary education in this rural setting of Pakistan. Foster and Rosenzweig (2005) obtained results in India showing that the returns to schooling increased during the period of rapid technical progress called the "green revolution." In one of the most studied green revolution regions of Pakistan and India, Barro and Robert (2001), found that increased schooling improved the productivity of farmers as well as helping them acquire knowledge about preventing resource degradation (an emerging green revolution down side). Cultural beliefs are not receptive to modern farm inputs and appear not to be able economically take immediate advantage of the innovation programs (Goossens, 1994).

4.7.2 On-farm processing

The major on-farm processed product found in the three villages in the district were dried cassava chip traditionally known as *makopa and chinyanya*. Wet fermentation was practiced in some households within the Newala district. Most farmers process *makopa* from bitter cassava and remnants left after selling fresh cassava roots from sweet cassava.

Generally, the amount of processed *makopa* was low as it was mainly for family consumption. The processing of *makopa* and *chinyanya* was done traditionally by hand peeling and chipping into small chips, and then dried. This made the processing labour intensive, time consuming, tiresome resulting to low processed quantities. In order to reduce the workload and increase efficiency, appropriate technologies were required which include simple machines for peeling and chipping.

The households interviewed stated that in normal years cassava was processed by prolonged direct sun-drying of whole peeled or split roots into makopa which when fully dried could be stored until when pounded into flour and some few areas practiced wet fermentation especially in Malatu and Songambele villages in Newala district. During the food shortage period the established processing methods were replaced by two short-cut methods. The first was to process "chinyanya", which involved pounding fresh peeled roots into small pieces and sun-drying. This procedure was repeated several times until sufficient flour was sieved out for making stiff porridge the same day. The second short-cut method involved slicing fresh peeled roots into small finger-size pieces, which were sun-dried on the rocks to dry fast. The small-size makopa could be pounded into flour within one or two days. Mlingi (1992) reported that, populations growing cassava in southern part of Tanzania usually knew how to process cassava into safe products but due to food shortage they had no other choice than to shorten the processes and hence obtained unsafe products. Normal processing time was reduced because of the emergency and so there was no proper detoxification. After about four to six hours they suffered from nausea, vertigo and confusion. There followed a sudden appearance of many cases of spastic paraparesis of legs, indicating an extensive epidemic. Outbreaks have been reported during the dry season from southern part of Tanzania (Mlingi *et al.*, 1995). During the food

shortage a relish of cassava leaves (*kisamvu*) was frequently used to supplement stiff porridge.

4.7.2.1 Constraints to cassava processing

In the study area it was observed that traditional processing methods were so laborious that mechanized processing was inevitable to improve labour productivity. The drudgery associated with traditional processing was enormous and the products from traditional processing methods were often contaminated with undesirable extraneous matter. Some of the products were therefore not hygienic hence become of poor market value.

Table 13: Constraints to cassava processing (n =120)

Processing constraints	Frequency	Percentage
Inadequate processing facilities only	2	1.6
Lack of enough knowledge on processing	5	4.2
Labour intensive only	2	1.6
Inadequate processing facilities and lack of enough knowledge on processing	11	9.2
Lack of enough knowledge on processing and labour intensive	5	4.2
Inadequate processing facilities and labour intensive	12	10.0
Both	83	69.2
Total	**120**	**100.0**

Also extension officers revealed that traditional cassava processing was time consuming. Of those interviewed, 1.6% of the respondents revealed that they thought inadequate facilities was only the constraint for cassava processing. On the other hand 4.2% stated that lack of processing knowledge was only the constraint to processing, 1.6% stated that the

only constraint to cassava processing was labour intensity. Another 9.2% stated that inadequate processing facilities and lack of enough processing knowledge were the only constraints for cassava processing while 4.2% stated that lack of adequate processing facilities and intensive labour were the only constraints for cassava processing. Ten percent of respondents stated that inadequate facilities and intensive labour were the only constraints to cassava processing. However, the majority 69.2% admitted that both (inadequate processing facilities and intensive labour required) were major constraints to cassava processing (Table13). Goossen (1996) reported that, cassava farmers from many African countries faced different processing constraints such as; failing innovation of processing technology, lack of adequate processing facilities, processing methods used were labour intensive and they lack knowledge on cassava processing.

It is reported that during the rainy season, sunshine and ambient temperatures are relatively low for processing cassava, particularly in lowland humid areas where cassava is mainly grown and utilized. In other localities, particularly in savanna zones, water, which is essential for processing cassava, is not easily available. During the early rainy season, the dry matter content of roots is usually lower than in the dry season, which can result in a lower yield of products. In the dry season when the soil is hard, harvesting and peeling tubers for processing becomes difficult and result in more losses (Nweke, 1994).

Cassava root shape varies among cultivars. Roots with irregular shapes are difficult to harvest and peel by hand, resulting in great losses of usable root materials. Root size also varies with cultivars although it depends more on environmental factors such as soil. Smaller roots require more labor for peeling. Varietal differences in dry matter and starch

content influence the output and quality of the processed products. Cyanide content varies with varieties, but is also affected by the crop growth environment (Dixon, 1989).

Harvesting and transporting of roots from farm to homestead and subsequent processing are mainly done by women. Most of the steps in processing are carried out manually using simple and inexpensive tools and equipment that are available to small farmers. Cassava processing is labor intensive and productivity is usually very low. Transport of products to markets is made difficult by the poor condition of rural roads. Subsistence farmers harvest cassava when needed. Thus they leave the cassava in the ground for long periods, believing that the cassava is safer and would undergo less damage than when harvested. Although this system has certain merits, a delay in harvesting can result in root losses due to root rots, damage by animals, and a decrease in the starch content in roots. Furthermore, keeping cassava in the ground prevents the use of that land for other purposes (CGIAR, 2002).

4.7.3 Consumption of staple foods

The trend in Table 14 below shows that of all the respondents, 71.7% consumed cassava as staple food while 28.3% relied on maize. 60% of households had processed and consumed *Chinyanya*.

Table 14: Consumption of staple foods (n = 120)

Crops	Frequency	Percentage
Cassava	86	71.70
Maize	34	28.30
Total	**120**	**100.0**

Extension officers and village leaders stated that acute intoxications after cassava meals were frequent in several villages in Newala District during drought seasons in recent years. All the interviewed households were informed about cassava intoxication following consumption of cassava stiff porridge during the food shortage.

4.7.3.1 Experience of intoxication from consumption of cassava by family members

Table 15 indicates that about 75% confirmed that family members experienced intoxications on several occasions. The intoxications were reported to be manifested through vomiting, dizziness, nausea, palpitation, weakness, diarrhoea, and headache and difficulty in vision.

Table 15: Experience of intoxication by family members (n = 120)

Intoxication	Frequency	Percentage
Experienced intoxication	90	75.0
Not experienced intoxication	30	25.0
Total	**120**	**100.0**

Similar finding was reported by Mlingi *et al.* (1992). Several documentations of cassava poisoning exist in East Africa (Bontinck 1990, Parke 1891, Casati 1995). Two lethal cases of poisoning following eating of sweet cassava (Manihot aipi) were reported from Pemba Island. Sporadic poisonings were reported in Kenya between 1980 and 1986 (Imungi 1986). These case reports from eastern, central, Nyanza and western provinces included a total of 13 deaths and 14 hospitalized patients. A rural outbreak of acute poisoning following cassava meals was documented during drought period in a cassava-growing community in northern Mozambique when insufficiently processed products were consumed (Essers *et al.*, 1992).

4.8 Laboratory results

4.8.1 Residual cyanide content of cassava samples

The laboratory results showed high total cyanogens levels of about (790 ± 107 mg HCN equivalent/Kg dry weight) and (263 ± 71 mg HCN equivalent/Kg dry weight) in flour obtained from both small and large-size makopa respectively but cyanohydrin levels were higher (39 ± 5 mg HCN equivalent/Kg dry weight) in chinyanya compared to levels of (7 ± 2 mg HCN equivalent/Kg dry weight) in the flour from large size makopa collected in the households as indicated in Table 16 below.

Table 16:Cyanogen levels in different cassava products from Newala

Cyanogen level	Chinyanya (n=19)	Small size makopa (n=19)	Normalsize makopa (n=12)	Fermented root (n=19)
Glucosides	91 ± 17	768 ±107	250 ± 70	3 ± 1
Cyanohydrin	39 ± 5	15 ± 4	7 ± 2	36 ± 7
Hydrogen cyanide	6 ± 1.0	7 ± 0.5	6 ± 0.5	13 ± 6
Total cyanogens	136 ±18	790 ± 107	263 ± 71	52 ± 7
Moisture (%)	13.5 ± 5	10.8 ± 0.2	10.6 + 0.4	

Values are given as mean ± SEM

Cyanogen levels are in mg HCN equivalent/Kg dry weight

Prolonged sun-drying of bitter cassava roots into makopa considerably reduces the amount of cyanogenic glucosides (Mlingi *et al.,* 1992). However, independently of the rate and completeness of drying, it seems that about 10% of the initial glucosides remain in the flour as indicated from makopa collected from households. Cyanohydrin levels found to be high in flour obtained from chinyanya might be due to insufficient drying. Banea *et al.* (2000), found that the amount of cynohydrins remaining in the cassava root depend much on the final moisture content, the higher the moisture content where the higher the

cyanohyrins level and vice versa. Therefore from these results it can be concluded that the roots obtained from the households were insufficiently sun-dried.

From the results, small size makopa showed high glucoside content of about (786 ± 107 mg HCN equivalent/Kg dry weight) compared to large-size makopa with (250 ± 70 mg HCN equivalent/Kg dry weight) followed by chinyanya with (91 ± 17 mg HCN equivalent/Kg dry weight). This has been explained by Mlingi *et al.* (1992), that if the roots are cut into small finger size pieces, they dry faster than the whole root but higher glucosides levels will remain.

Extension officers stated that the population was aware that *makopa* should be sufficiently sun-dried before pounding into flour for stiff porridge. A brittle sound should be heard on breaking a piece of *makopa* to indicate that it was ready. Depending on size, type of roots and weather, *makopa* were ready for pounding into flour after one or more weeks of sun-drying. However, this principle was not adhered to by poor households during food shortage because they had no other alternative foods to eat. Chinyanya processing was known by all the three village women but they stated that it was only practiced during food shortage periods. Processing into small size *makopa* was also practiced during favourable years because cassava roots were splint into smaller sizes so that they could dry faster.

Mlingi *et al.* (1995) reported that sun drying of whole cassava roots does not achieve sufficient cell disintegration to bring the linamarase enzyme into contact with cyanogenic glucosides to achieve hydrolysis. But on the other hand thin slices can dry very fast, thus reducing the moisture content to a level that inactivates the enzyme before tissue disruption enabled it to act on the cyanogenic glucosides. Although sun drying of the bitter varieties

reduces the amount of cynogenic glucoside considerably, about 10% of the initial cyanogenic glucosides remain in flour (Anon,1984; Mlingi *et al.*, 1992; Mlingi *et al.*, 1995) Studies by several workers have shown that cyanogens are reduced to negligible levels by processing such as grating and soaking, followed by sufficient heating or sun-drying. All procedures leading to tissue disintegration without heating lead to release of the endogenous linamarase enzyme and result in glucoside hydrolysis. Glucoside removal can also be enhanced by direct leaching into the soaking water (Nambisan and Sundaresan 1985, Vasconcelos *et al.*, 1990; Hahn, 1989). It has been observed that fermentation in air is not as effective as that in water (Mahungu *et al.*, 1987) but heap fermentation of whole or split roots studied in Uganda showed that the process was significantly more effective than sun-drying alone (Essers *et al.*, 1992). The present studies support earlier findings that all processing methods to which cassava is subjected rapidly remove the hydrogen cyanide yielded, and the remaining cyanogens are mainly cyanohydrins and glucosides (Coursey 1973, Cooke and Maduagwu 1978. El Tinay *et al.* 1997; Ayernor, 1998; Ezeala and Okoro, 1986). The direct sun-drying used in southern Tanzania is not effective in reducing cyanogens. The reason is most probably that it does not achieve sufficient cell disintegration to bring the linamarase enzyme into contact with the glucosides to achieve hydrolysis. The breakdown of the cyanohydrins formed can be achieved by sufficient drying, and consequently flour from well dried makopa contained low levels of both hydrogen cyanide and cyanohydrins, whereas considerable amounts of glucosides remained in the flour. When processing methods were shortened during food shortage the products were not sufficiently sun-dried which resulted in high remaining amounts of cyanohydrins. Such a situation happened in Newala District, Southern Tanzania during chinyanya processing. Pounding of fresh roots in a mortar followed by alternate sun-drying and repounding gave a product with high cyanohydrins level. Slicing of roots causes

minimum tissue disintegration. When followed by rapid drying it results in high retention of glucosides, probably because the linamarase enzyme is rapidly inactivated during the drying process.

4.9 Flour quality (colour and nutrient retention after processing)

The households revealed that the final flour obtained from chinyanya was white in colour; flour obtained from dried makopa was cream in colour while flour obtained from fermented root was sometimes grey or yellow in colour. Clerk *et al.* (1968) reported that, processing methods such as solid fermentation and sun drying encompass a range of conditions under which mould growth is likely to occur and change the colour of the root to grey or yellow.

4.9.1 Color preference

Results in Table 17 above below shows that, about 79.16% of the respondents interviewed stated that they prefer the white colour of flour from chinyanya but due to side effects after eating such as vomiting, diarrhea and headache; they use flour from dried makopa as an alternative.

Table 17: Color preference (n = 120)

Color of flour	**Number of respondents**	
	Frequency	Percentage
White	95.0	79.2
Grey	19.0	15.8
Yellow	6.0	5.0
Total	**120.0**	**100.0**

During drought season due to lack of enough food people had no alternative and use flour from chinyanya because it is easy to prepare within a short period of time. 15.8% of the respondents interviewed preferred grey flour while 5% of the total respondents stated that they prefer more yellow flour, thus the results imply that the majority of the people consuming cassava preferred white flour. These findings are supported by Thomson *et al.* (1996).

4.9.2 Nutrient retention before and after processing

Laboratory results from Table 18 below shows that, protein content of makopa flour (2.72 g/100g) was high compared to protein content of chinyanya flour (1.3 g/100g) and flour from fermented root (0.75 g/100g). This showed the same trend as the results obtained by Padmaja *et al.* (1994). They urgued that protein tends to leach into steeping water during fermentation as a result of micro-organisms breaking down the cell membrane. Sun drying caused small changes in protein content of cassava. A slight decrease of protein in sundried cassava was also reported by Maini *et al.* (1991).

Table 18: Nutrient retention and after processing

Nutrient	Fresh cassava root	Flour from chinyanya	Flour from makopa	Flour from fermented root
Starch (g/100g)	71.80	72.00	80.00	65.20
Protein (g/100g)	0.75	1.30	2.72	0.75
VitaminC(mg/100g)	34.00	32.80	24.52	15.40
Moisture (g/100g)	63.90	18.70	12.50	13.70
pH	6.45	13.22	10.28	5.25

An average vitamin C content of chinyanya flour were high (32.8 mg/100g) compared to Makopa flour (24.52 mg/100g) and flour from fermented root (15.4 mg/100g). Comparing these values with fresh cassava which contain vitamin C between 82-133mg/100g dwb

(FAO, 1972; Watson, 1976; Lancaster *et al.*, 1982; Cock, 2001) it can be concluded that vitamin C is not very stable and usually is destroyed during processing through combined action of heat, oxygen and light. It has been reported that prolonged drying time increases vitamin C losses. Drying has also been shown to reduce vitamin C content of other products like, red pepper and union flakes (Park, 1975; Powar *et al.*, 1988).

Wet fermentation shows very low vitamin C value compared to sun-drying process. This shows that there is considerable loss of vitamin C during fermentation. Fresh cassava has been reported to contain vitamin C between 82-133 mg/ 100g dry weight basis (FAO, 1972; Lancaster *et al.*, 1982; Cock, 2001).

Moisture content of cassava flour obtained from *chinyanya* was high (18.9 g/100g) compared to *makopa* (12.5 g/100g) and this was due to the fact that in *chinyanya* processing the root is dried within a short time while in *makopa* processing the root is dried for long time. Fish and Trim (2001) reported that inadequately processed cassava has limited shelf life. Gerona (1986) and Sajise and Ilag (1997) found that cassava chips dried to 11-14% moisture on dry weight basis can be stored for up to 4 months without deterioration.

On the other hand samples from wet fermentation showed values of starch content of about 65.2 lower than the starch content of fresh cassava root (71.8 g/ 100g dwb) while *makopa* and *chinyanya* flours showed little effect on starch content. Comparing these values to the reported starch content of the fresh cassava which ranges between 73.7-84.9 g/100g dwb (Rickard *et al.*, 2001; Asiedu, 1992) it can be concluded that chinyanya processing had little effect on starch content of these cassava roots but long term drying

had an effect on starch content. Fermentation of cassava can cause reduction of starch content of up to 15-25% (Daubresse *et al*, 1987; Antai and Mbongo, 1994; Birk *et al.*, 1996). Khetapaul and Chaun (1990) also observed reduction of starch in pearl millet. They argued that starch degradation is caused by amylolitic action of micro-organisms in the fermenting mixture.

Table 16 shows the pH values of cassava flour samples processed by different methods. Samples processed by wet fermentation had low pH values of (5.25), while sun dried samples had the highest pH values (13.22 and 10.28 from *chinyanya* and *makopa* flour respectively). Production of organic acid (mainly lacti acid) during fermentation causes the fall in pH (Arinkele, 2001; George *et al.*, 1995). Organic acid production during rotting has been also reported by Ampe *et al.* (2000).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, several processing methods can render cassava safe for consumption by removing the large quantities of glucosides present as well as the resulting products of hydrolysis, the cyanohydrins and hydrogen cyanide. Shortcuts in processing can result in considerable dietary cyanide exposure in an apparently unpredictable way. This may even be the case when so-called low cyanide variety (defined as having less than 150 mg cyanide equivalents per kilogram of dry weight when harvested) are used. The majority of these cyanogens must be removed by processing to reach the level of 10 mg per kilogram considered safe for consumption.

These findings confirm that direct sun-drying of cassava roots is an ineffective method for removal of cyanogenic glucosides as it yields products with relatively high residual levels of cyanogenic glucosides. Fermentation of cassava root is effective method in removal of total glucosides although key informants stated that it is practiced in very few areas due to the unavailability of enough water for fermentation. However, it shows considerable loss of starch, protein, vitamin C. From the findings of this study it can be concluded that although wet fermentation showed high nutrient loss from the health point of view it is an effective way of reducing cynogenic glucosides level from cassava root which are dangerous for human health. It is therefore suggested that enhancing ability of cassava processors to adopt more effective cassava processing methods has great potential for producing high quality cassava products.

If the food security provided by cassava is to have an optimal health impact, the nutritional drawbacks of cassava must be minimized. The results of this study indicate that cyanogenic glucosides in roots of bitter and toxic cassava varieties can be considerably reduced through processing, but effectiveness varies between different methods. Where less effective processing methods are used, toxicity may be avoided by exclusive cultivation of non-bitter varieties with low glucosides levels in the fresh roots. Hence the effectiveness of processing technique needs to be related to type of cassava cultivars grown in each area of the country. The findings father indicate that the use of short-cuts in cassava processing due to food shortage seems to be the main determinant for high dietary cyanide exposure from cassava. Diseases attributed to cassava toxicity seem to appear in very poor rural communities during periods with severe agricultural and economic problems. The study done in Newala District was not based on representative sample from large cassava producing areas and therefore the results can not be used to quantify the problem in the whole country but it was found that the common processing method used in this district is drying of whole and small size cassava roots and wet fermentation is practiced in some few areas. However, it can be concluded that many cassava growing areas of Tanzania are at risk of toxic effects of cassava and that prevention is feasible through promotion of effective processing.

5.2 Recommendations

(i) From this study it is recommended that cassava eating population who cannot practice wet fermentation because of their environment or climatic conditions need to be advised, encouraged and trained to practice grating followed by solid-state fermentation. This will reduce the cyanogens content to safe levels.

(ii) The adaptability of roots and tubers to marginal environments, their contribution to household food security, and their flexibility in mixed farming systems and end uses make them an important component of a targeted strategy for improving the welfare of the rural poor and linking smallholder farmers to markets. To accomplish this, continuous generation and diffusion of improved production and post harvest technology is essential, as are policies and institutions that facilitate adoption of this technology. Such efforts will prove successful only if the public and private sectors make substantial investments in agricultural research to overcome the obstacles to greater root and tuber production and use. Cassava mainly faces demand-side constraints. In its case, lower costs, better quality and improved availability of raw material, and more efficient small agro-enterprises can help producers exploit latent demand for this crop as feed and processed food products.

(iii) Better processing methods can improve the life-styles and health of rural people through higher processing efficiency, labor saving and reduced drudgery, all of which can improve the quality of products.

(iv) Appropriate policies in both developed and developing countries are needed to ensure that the environmentally sound production of a diversified range of high-quality, competitive root and tuber products for food, feed, and industry will help eradicate poverty, assure access to adequate food, and improve incomes. Policymakers in developing countries can support this effort by, for example, eliminating overvalued exchange rates, subsidies on imported substitutes, and

policy distortions that promote the improper use of pesticides and fertilizers on roots and tubers.

(v) Policy makers in developed countries can help improve the growth prospects for roots and tubers in developing countries by, among other things, abandoning trade arrangements that limit import demand for these commodities, eliminating subsidies on exports of competing food products, and facilitating technology transfer to strengthen local production and use of roots and tubers (for example, small-to intermediate-scale processing equipment and expertise).

(vi) Cassava is a strategic crop for future generations of Africa, adding that with increasing urbanization rates in the region, cassava products could offer a response to the growing demand for food, which otherwise, would have had to be imported. Apart from processing cassava into different products for local consumption other opportunities also exist for the development of high quality cassava flour, supply chains for starch, ethanol and animal feed industries.

(vii) The solutions to the nutritional problems associated with cassava are unlikely to be resolved by eliminating cassava from the diet: the population would probably die of starvation rather than merely being malnourished. The solution seems to lie with improved processing and providing a more varied diet with the necessary supplements such as iodine and protein sources to populations at present entirely dependent on cassava for their nutrition. In the case of children, the importance of a more varied diet is particularly important. Therefore, better cassava processing and storage techniques appropriate to the country will have to be developed if full benefits are to be obtained.

(viii) Opportunities for improving cassava on-farm processing into more products are important as, these will enable farmers add more value to their produce and

therefore diversify their markets for better prices and incomes. The existing opportunities include:

a) Farmers were willing to expand their cassava production because the region has unreliable rainfall and cassava is one of the crops that can grow and produce dependable yields in places where cereals and other crops fail. Cassava is also highly flexible in its management requirements, and has potential of high energy production per unit area of land;

b) Cassava can be processed into many products and therefore a high demand can be created if well targeted. This assures increased incomes to many small-scale cassava producers if proper technologies are used. For example, cassava forms the basis of a multitude of products, including food, flour, animal feed, alcohol, starches for sizing paper and textiles, sweeteners, prepared food and biodegradable products. The products are derived from a number of forms of cassava, ranging from fresh leaves and roots to modified cassava starch. The degree of processing and technical requirements tend to increase from the fresh form to modified starch;

c) The region still has plenty of unutilized and suitable land for farming which can be properly utilized if on-farm processing is expanded and makes the crop more profitable. It is obvious that on-farm processing can easily stimulate adoption of appropriate technologies and therefore cause an increase in production and marketed volumes. This will create employment and consequently more engagement in agriculture production.

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APPENDICES

Appendix 1: Questionnaire

EFFECT OF DIFFERENT LOCAL CASSAVA PROCESSING METHODS ON CYANOGENIC GLUCOSIDES LEVEL, NUTRIENT RETENTION AND COLOUR OF CASSAVA FLOUR.

Questionnaire No ....., Date of the Interview ..... Interviewer's name .....
Name of the respondents .....
Ward ..... Village .....

Module 1: Processor (Farmers Characteristics)

1.1 Age the Farmer (processor)

1.2 Genders of the respondents

1 = Male 2 = Female

1.3 Marital status

1 = Married 2 = Single 3 = Widowed 4= Divorced 5 = Others (Specify)

1.4 Education level of the respondents

1= No formal education 2 = Primary education 3 = Secondary and above education 4 = Post secondary education

1.5 Household size (numbers) .....

1.6 Age composition

Age group	Number (size of age category)
Below 17 years	
17 – 50 years	
Above 50 years	

1.7 Main source of income

Source	Income/year or month
1 = Farming	
2 = Livestock	
3 = Informal sector	
4 = Wage/salary employment	
5 = Off farm activities (not wage employment)	

Module 2: Cassava Production

2.1 What varieties of cassava are you growing

i. .....

ii. .....

iii. .....

2.2 Which one is less attacked by pest and why .....

2.3 What are the major problems facing you in cassava production

i) .....

ii) .....

iii) .....

iv) .....

2.4 What should be done to improve cassava production

.....

.....

.....

2.5 Is the accessibility to free family labour enough

1 = Yes

2 = No

If no why

2.6 Is cassava the staple food

1 =Yes 2 = No

If no which is crop the staple food

2.7 Extent of accessibility to family labour

1 = Low accessibility to free family labour

2 = High accessibility to free family labour

3 = No accessibility to free family labour

Module 3: Cassava Processing

3.1 Do you process your cassava products/Output

1 = Yes

2 = No

3.2 Why do you process your cassava products

1 = To make it convenient for use

2 = To make it palatable

3 = To remove toxicity (cyanide)

4 = Others (specify)

3.3 When did you started processing cassava .....

3.4 What persuaded or motivated you to process cassava

1 = Cash value from processed product than raw produce

2 = Cassava peels for livestock

3 = For home consumption

4 = Others (specify) .....

3.5 Where do you process your cassava produce

1 = To small cassava processors inside the village

2 = Ourselves

3 = Others (specify)

3.6 What are the local processing method used

.....

.....

.....

.....

3.7 What processing methods and tools do you use

ii. .....

iii. .....

iv. .....

v. .....

3.8 Which processing method do you prefer most and why .....

.....

3.9 How far is your processing machine from your home ..... Km

3.10 How many kgs of cassava flour did you obtained from processing .....

Kgs.

4.0 What is the quality of your cassava products (processed) in general

1 = Good

2 = Poor

3 = Satisfactory

4 = Others

4.1 What are the colour of the flours obtained

.....

.....

.....

4.2 Which colour of flour are most preferred.....

4.3 What are the constraints to cassava processing

.....

.....

.....

4.4 Do you experience and intoxication problems from cassava consumption

1 = Yes

2 = No

If yes what are they

.....

.....