KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCE

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

EFFECT OF POST-HARVEST MANAGEMENT ON CASSAVA PRODUCTION, PROCESSING AND QUALITYOF STARCH PRODUCED DURING GARI-MAKING

BY

EMMANUEL AMENU

JUNE, 2015

EFFECT OF POST-HARVEST MANAGEMENT ON CASSAVA PRODUCTION, PROCESSING AND QUALITYOF STARCH PRODUCED DURING GARI-MAKING

BY

EMMANUEL AMENU

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA IN PATIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN POSTHARVEST TECHNOLOGY.

JUNE, 2015

DECLARATION

I declare that this dissertation being presented for the award of Master of Philosophy Degree in Postharvest Technology is the result of my own work except for the reference made from publications of some authorities which has been duly acknowledged, and that this work has not being submitted for any degree in any university or college.

SUBMITTED BY:	SIGNATURE	DATE
EMMANUEL AMENU	…………………………	……….…………
(PG 4180910)		

CERTIFY BY:	SIGNATURE	DATE
PROF NANA OLYMPIO	………………………..	………………….
(SUPERVISOR)		

CERTIFY BY:	SIGNATURE	DATE
DR FRANCIS APPIAH	………………………	….…………….
(HEAD OF DEPARTMENT)		

DEDICATION

I dedicate this work to my wife Mrs. Comfort Ama Amenu and children Roseline Akpene, Emmanuella Makafui, Samuel Selasi and Daniel Elikplim.

ACKNOWLEDGEMENT

My first and foremost thanks go to the Almighty God who by his steadfast love and mercy has seen me through this course.

I am thankful to my supervisor, Professor Nana Sakyiwa Olympio for her moral support, encouragement, helpful comments and suggestions which have made this work what it is.

I thank all lecturers at the Horticulture Department for the efforts they put in shaping my work and also preparing me for any future endeavours.

I will not forget the special contributions made by Mr. William Kobla Heve, a PhD student of University of Florida and Dr. Charles Etse, my current boss (the Suhum Municipal Director of the Department of Food and Agriculture (DoFA)).

In a very special way I want to express my deepest appreciation and gratitude to my former boss, Mr. Samuel Yaovi Dotse for their moral support and advice throughout the programme. The entire staff of MOFA also deserves appreciation especially the Agricultural Extension Agents who helped in the questionnaire administration.

Finally, my thanks go to all those who in diverse ways helped me to complete my course. May the almighty God shower his blessings upon you all!

Abstract

Cassava is a major staple food crop characterized by its cultivation, processing and uses. The survey was to study the effect of post-harvest management on cassava production, factors affecting post-harvest management of cassava and quality acceptability of *tapioca* in different kinds of foods prepared from *gari*. Data of cassava yield and production were obtained from the District Department of Food and Agriculture and SRID-MoFA. Additional data were obtained by randomly selecting and interviewing 100 each of processors and consumers in 6 study zones of the district. *Tapioca* and *gari* were produced from the four common varieties of cassava for the analysis of *gari: tapioca* ratio and the acceptability of quality of different food kinds prepared from *tapioca* and *gari.* The results showed that the collapse of cassava processing factory in the district is causing a continuous decline in the annual cassava production, which can likely result into a localised food crisis in subsequent year(s). However, post-harvest processing of cassava mainly depended on the availability of cassava in the district, many years of experience of processors, acceptability of simple packaging and high consumer preference for ethnic-based products. The quantity of *tapioca* from starch suspensions, usually discarded during *gari* processing, is about one-eighth of the weight of *gari.* The new products (soakings of a mixture of *tapioca* and *gari*) have higher quality acceptability than *eba* from *tapioca* and/or *gari.*

TABLE OF CONTENT

CONTENT **PAGES**

Declaration………………………………………………………………………………………. I

Dedication………………………………………………………………………………………. II

Acknowledgement………………………………………………………………………………III

Abstract…………………………………………………………………………………….... IV

Table of contents……………………………………………………………………………....V

List of tables………………………………………………………………………………….VIII

List of Figures…………………………………………………………………………… IX

CHAPTER ONE………… ……………………………………………………………………..1

1.0 INTRODUCTION……….……………………………………………………………….……1

CHAPTER TWO..4

2.0 REVIEW OF LITERATURE………………………………………………………….…….4

2.1 Botany of the cassava plant……………………………………………………………..4

2.2 Origin of cassava in Ghana………………………………………………………………..4

2.3 Soil and climatic suitability in Ghana……………………………………………………..6

2.4 Crop cycle………………………………………………………………………………….6

2.5 Varietal properties…………………………………………………………………………7

2.6 Cropping and harvesting………………………………………………………………10

2.7 Importance and uses of cassava…………………………………………………………..10

2.7.1 Ecological importance……………………………………………………………….10

2.7.2 Socio-economic importance of cassava…………………………………………..11

2.7.3 Nutritive value of cassava……………………………………………………...12

2.7.4 Uses of cassava……………………………………………………………………………12

2.7.5 Importance of post-harvest management of cassava…………………………………...13

CHAPTER THREE…………………………………………………………………...14

3.0 MATERIALS AND METHODS……………………………………………………...14

3.1 Description of the study area……………………………………………………………..14

3.2 Survey, sampling and data collection………………………………...………………..14

3.3. Analytical procedures……………………………………………………………….………17

3.3.1 Dry matter content of cassava…………………………………………………….………18

3.3.2. Starch content of dry matter…………………………………………………………...18

3.3.3. Starch solubility………………………………………………………………………..18

3.3.4. Water absorption of starch………………………………………………………….……18

3.3.5. ph(supernatant) and quantification of gari and starch…………………………………19

3.3.6. Sensory evaluation for acceptability of quality………………………………………20

3.4 Data analysis………………………………………………………………………………21

CHAPTER FOUR…………………………………………………………………… 22

4.0 RESULTS……………………………………………………………………………..…….22

4.1 Contribution of cassava production in the district……………………………………….22

4.1.1 Properties of cassava produce………………………………………………………….25

4.2. Post-harvest management of cassava…………………………………………………25

4.2.1 Experience, training and adoption………………………………………...………25

4.2.2 Sufficiency, processing and handling…………………………………………...…….. 28

4.3 Post-harvest processing of cassava into tapioca and gari……………………………… 30

4.4. Quality, preferences and packaging of different food products from gari and tapioca………………………………………………………………...32

CHAPTER FIVE……………………………………………………………………...36

5.0. DISCUSSIONS………………………………………………………………………..36

5.1. Effects of post-harvest processing on cassava production pattern………………………36

5.2. Factors affecting post-harvest management of cassava in the district…………………..37

5.3 Post-harvest cassava processing induced starch losses………………………..…………38

5.4 Improving the quality of tapioca in gari………………………………………………… 39

CHAPTER SIX……………..41

6.0 CONCLUSION AND RECOMMENDATIONS……………………….………...……...41

6.1 Conclusion…………………………………………………………………………… 41

6.2 Recommendations………………………………………………………………… 41

REFERENCES……………………………………………………………………………….. 42

APPENDICES………………………………………………………………………50-55

LIST OF TABLES

TABLE **PAGES**

The average yield and uses of some cassava varieties in Ghana……………………9

Population of the District based on the six zones………………………………...17

The 7-point headonic scores used for the acceptability of quality of products……...20

Some selected poperties of mature cassava produce from four different varieties…25

Factors relating to improving skills of processors………………………………..27

1. Proportion of processors and consumers for the cassava products available

   in the district……………………………………………………………………..29

Purposes of improving nutritive value and packaging cassava products…………. 30

Estimated quality acceptability for the different food products from

gari and tapioca……………………………………………………….…………...34

Consumer preference level for the possible cassava products from the various varieties

………………………………………………………………………….……..35

Shelf-life and status of packaging types for marketing processed products………...35

LIST OF FIGURES

Figures **Pages**

1. The spread of cassava to Ghana and other parts of the world………………………... 5

2. The stages of cultivated cassava in the district ………………………………………. 7

3. Study zones and communities of Suhum Kraboar Coaltar District in a cassava producing area of Ghana...16

4. Annual contributions of crops to the major staple food crop production: national and Suhum District data…………………………………………………………………………. 23

5. Production and yield indices of cassava in the Suhum Kraboa Coaltar District (SKCD)…………………………………………………………………………………….. 24

6. The major source of cassava for processing in the district…………………………...28

7. The commonest cassava processing activities and processed products present in the Suhum Kraboa Coaltar District. #: intermediate ; *: eaten as finished ……………..31

8. Comparison of gari and tapioca from roots of mature cassava varieties……………. 32

CHAPTER ONE

1.0 INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a staple root crop, which originated from the Central America and is now cultivated in tropics and consumed by millions of people. Cassava is used for the preparations of various food kinds in many industrialized processes (Dufour, 1994; Hahn *et al*., 1987). Although it was not initially well known outside the tropics, cassava now accounts for about 30% of the tropical staple food crops for over 200 million people in Africa (Dufuor, 1994); cassava plays a major role in alleviating food crisis in Africa because of its high food energy, all-year-round availability and tolerance to grow in extreme stress conditions (Hahn and Keyser 1985, Hahn *et al*., 1987). Cassava can be grown on marginal lands or to improve fertility status of poor soils, making it suitable for the cultivation of other crops (Cocks, 1985) because the root of cassava ecologically form useful symbiotic association with mychorriza, which can increase available plant nutrients (Liu *et al*., 2002; Ceballos *et al*., 2013), improve soil moisture, suppress soil borne pests such as crop root feeding nematodes (de la Peña *et al*., 2005). It is propagated by planting cuttings (about 15 cm long) of the woody stems of mature plants. Mature tubers are harvested after 9-12 months depending on varieties.

Fresh raw cassava tubers are highly perishable with a shelf life of less than 4 days after harvest (Phillips *et al*., 2004). Generally, the fresh tubers contain 60-65% moisture (Bradbury and Holloway, 1988; Cardoso *et al*., 2005) and hydrocyanic acid, which can be toxic to humans (Cardoso *et al*., 2005) and give bitter taste (King and Bradbury, 1995). In Ghana, fresh cassava tubers (the raw produce) are firstly processed into primary products such as *ampesi*, *agbelima*, dry cassava chips and starch to reduce the cyanic acid and moisture contents. Further processing of the primary products results into intermediates or finished forms. In some cases, processing of cassava is to improve quality and add value to the finished products (Cardoso *et al*., 2005) creating opportunity to increase longevity of the products for storage (Hillocks, 2002), improve palatability, facilitate transportation and marketing (Hahn, 1988). Unfortunately, it is not a usual practice of the cassava processors to improve the nutritive value of the high carbohydrate content of the processed products (Sekle, 2011).The peels of the tubers and the fresh leaves are usually suitable as feeds for livestock (Oppong-Apane, 2013).

However, it is not all the raw cassava produce that is processed. Several factors such as high fibrous content of some products, damage due to pest and diseases (RTIMP, 2009; Banito *et al.*, 2010), inefficient traditional processing techniques (Hahn 1988) and difficulty associated with storing cassava and the products (Adu-Mensah *et al*., 2007; Gnonlonfin *et al*., 2008) account for post-harvest losses. Nweke *et al.* (1992) also revealed that about 42% of harvested cassava in West and East Africa are processed into dried chips and flour for storage though this work did not include consumer preference of the processed products. Similarly, Collinson *et al.* (2001) reported on the acceptable, convenient and hygienic traditional forms of processing and packaging of cassava products in Ghana but failed to account whether the trend in cassava production is more towards improving food security or not. Generally, information on the indicators of cassava production and their promoting factors are lacking in the Suhum Kraboa Coaltar District of Ghana. This information will provide clues as to whether cassava processing is linked to its availability or not.

Recently, there were concerns on safety and quality of processed cassava (Sanni *et al*., 2007; Oti *et al*, 2010). These situations made it impossible and unattractive for investors and other stakeholders to support the cassava sector in potential cassava zones of Ghana though there is still demand and consumer preference for cassava and its products (MoFA, 1997; González and Johnson, 2009).

In Suhum Kraboa Coaltar District of Ghana, cassava is processed into various forms of products. However, most cassava processors normally choose among different cassava varieties for specific properties of processed products. For example, the varieties, *afisiafi* and *duafra* give higher yield and attractive quality features of *gari* than others (Aboagyewaa, 2011). There is the need therefore to study the factors affecting post-harvest management of cassava into other products in the district. In effect, the study will be able to develop post-harvest management strategy of promoting the processing of some valuable contents of cassava for maximum use.

The main objective of the study was to examine the status of post-harvest management induced production, local cassava processing technique for most common products and alternative process of improving the quality of cassava product for consumption in the Suhum Kraboa Coaltar District.

This project was to

1. study the post-harvest management of cassava in the district.
2. analyze factors affecting post-harvest management of cassava in the district
3. analyse the effect of *gari* -making technique on post-harvest management of soluble starch.
4. assess the acceptability of quality of different food kinds from processed starch (*tapioca*) and *gari*

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 BOTANY OF THE CASSAVA PLANT

The genus *Manihot* is a member of the economically important family Euphorbiaceae to which rubber and castor belong (Tweneboah, 2000).

Cassava (*Manihotesculenta* Crantz) is a shrubby, short-lived perennial plant which can grow to a height of 3m or more, with an erect stem marked by prominent knobby leaf scars and vary degrees of branching, (Tweneboah, 2000). Branching is variable: some cultivars branch near the base and spread, others are erect and branch near the apex. Stems vary in colour, being grey, green, greenish-yellow, reddish-brown, or streaked with purple (Gooding, 1987). The branches carry large alternate, spirally arranged palmate compound, deeply lobed leaves on long petioles subtended by small deciduous stipules. The leaves tend to be clustered towards the top of the stem as those below are shed, leaving the prominent leaf scars (Tweneboah, 2000). The tuberous roots are in a cluster of 2-10 at the base of the stem with secondary branches of adventitious root which become thickened with stored food. The genus *Manihot* is a member of the economically important family Euphorbiaceae to which rubber and castor belong (Tweneboah, 2000).

2.2 ORIGIN OF CASSAVA IN GHANA

Cassava was initially cultivated in Brazil, Colombia, Venezuela, Paraguay, Mexico and other South American countries before 1600 (**Figure 1**) even though the exact place in the Central to South Americas is a subject of dispute. In the fifteenth century, the Portuguese were already colonising Brazil and were trading actively in the "slave trade" in Africa. According to Okogbenin *et al*. (2006), the Portuguese brought cassava from Latin Americas to feed slaves in West Africa in the sixteenth century. Later, cassava was taken to India in the seventeenth century and East Africa in the eighteenth. The movement of the European from Brazil to São Tomé and Fernando Po continued spreading cassava until it reached the central parts of the African continent. Also, the French who were colonising the Guianas and Réunion were mainly responsible for the transfer of cassava to the East African countries and Madagascar and later to Ceylon (Sri Lanka) in 1786. As a result, it was realised that the crop was tolerant to drought, low soil fertility and poor crop husbandry and served as a famine reserve crop (van Vark, 2013). As populations continued to increase, cassava was widely grown in West African countries including Ghana (Eke-okoro and Njoku, 2012) in the twentieth century to satisfy the increasing demand for food.

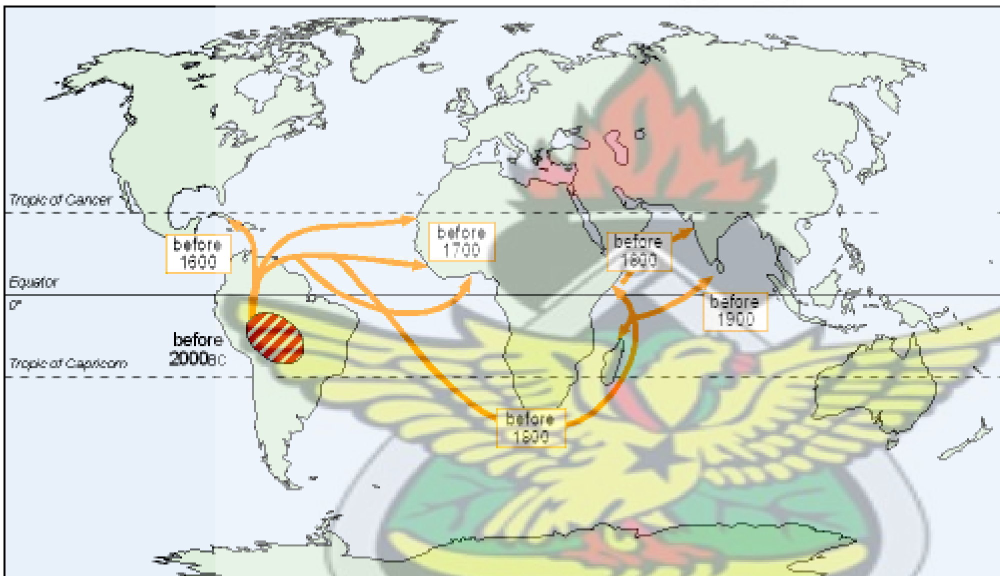

Figure 1. The spread of cassava to Ghana and other parts of the world. *Source:* London Natural History Museum (UK) (http://www.nhm.ac.uk/nature-online/life/plants-fungi/seeds-of-trade/page.dsml?section=timelines&timelineID=8&origTimeID=8&origTimePoint=4&origTpTitle=Into%20Africa&origPage=spread&page=spread&ref=cassava&timepoint=5).

2.3 SOIL AND CLIMATE SUITABILITY IN GHANA

Cassava is grown in all parts of West Africa south of latitude 12^0N but the main areas of intensive cultivation are in the semi-deciduous forest or the transition to forest areas

(Tweneboah, 2000). Cassava can be grown in most agro-ecological zones in Ghana because it can tolerate poor soils with low water content and nutrients. A site of sandy to deep loamy soils gives a better yield than heavy clayey soils as the crop requires loose soils for maximum rooting and root penetration into soils. Cassava plant is hardy and able to tolerate drought and poor soil conditions than most other food crops (Hillocks, 2001), and recover when foliage/stem is damaged by crop pests (Dufour, 1995).

2.4 CROP CYCLE

After harvesting the mature plants, healthy and disease-free stems are selected. Propagation is by planting the cuttings from the selected mature hard stems. The stems are stored in bundles under shades until used in the next cropping seasons (**Figure 2**). Farmers plant the cuttings (about 20-25 cm) (RTIMP, 2009) in fields against slopes to control erosion and for maximum rooting. Sprouting occurs after two weeks. At vegetative stage, the stems branch at one-third to two-third positions of the total stem height depending on the varieties (Doku, 1999). Stem branching with short internodes is more common at the apex. The branching minimizes as the plant approaches maturity. Mature cassava plants of most varieties in the district develop seeds and hard stems. Yellowing and defoliation of leaves increase as the plant matures (RTIMP, 2009). The tubers (food storage roots) of mature plant become bigger in size. Generally, farmers harvest mature cassava roots between 9- 12 months after planting depending on the variety (Gooding, 1987).

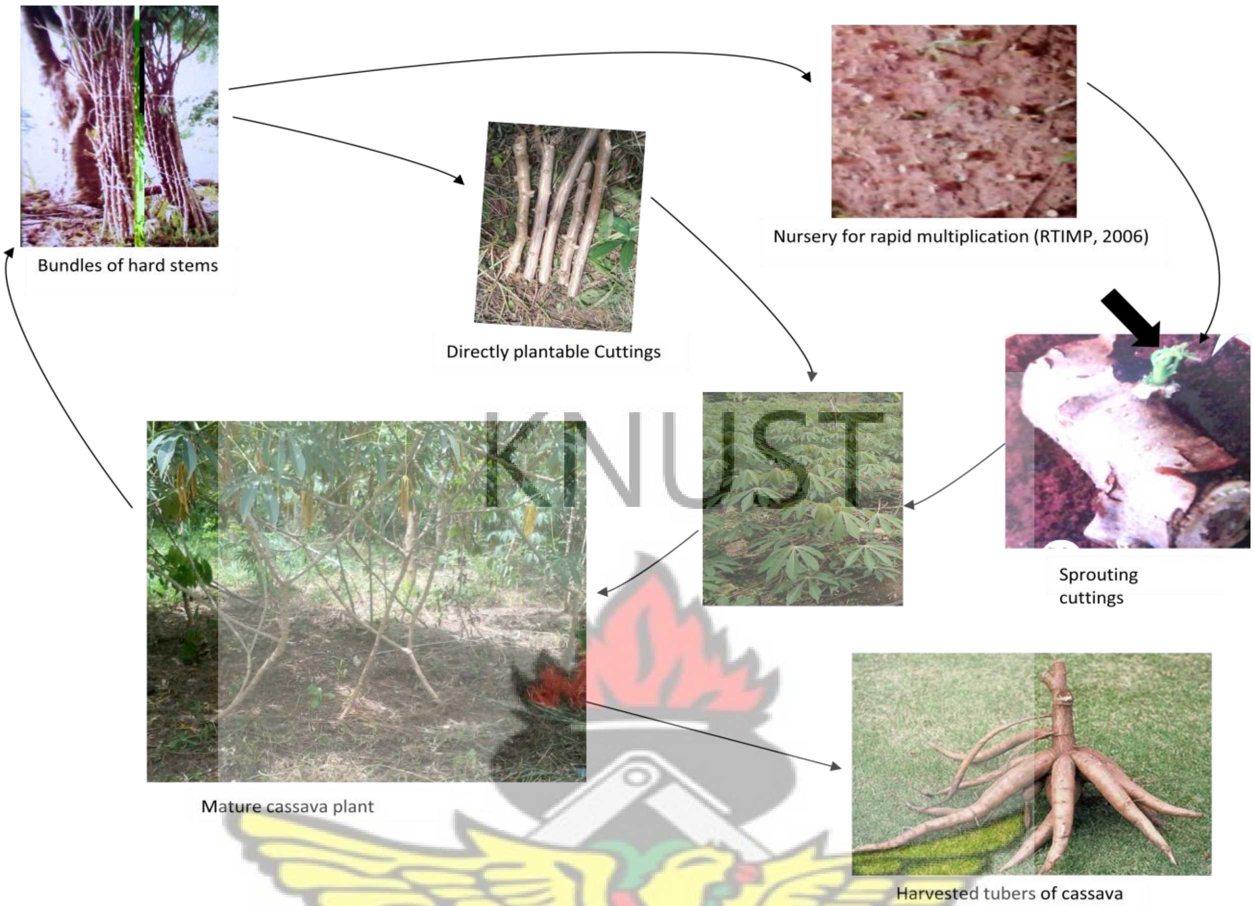

Figure 2. The stages of cultivated cassava in the district. *Source:* RTIMP (2006)

2.5 VARIETAL PROPERTIES

In Ghana, the varieties mainly known and grown by farmers are *Tuaka*, *Ankrah*, *Agege*, *Afram plains*, and many others (Doku, 1999; Tweneboah, 2000; CSD, 2013). Generally, the colour of petiole, stem, tuber, flesh of tuber and duration to maturity are used to distinguish among the varieties (RTIMP, 2006; CSD, 2013) (**Table 1**). Other properties such as stem branching, high yielding and height of the crop can be used to identify the variety (Gooding, 1987; Doku, 1999). However, it is impossible to predict the varietal origin of the processed products; similar products of different varieties normally physically look alike but may differ slightly in taste (Aboagyewaa, 2011). The general characteristics of the various varieties provide guide to both cassava farmers and processors. Selection of the variety depends on high yields, marketability and suitability for the products (Hahn, 1988). Root tubers of some varieties have higher moisture content and are more perishable; fungal attack usually causes tuber rots or discoloration and is responsible for most post-harvest losses. Therefore, the crops are not left to over-mature before harvesting (Egyir and Obeng, 2008; Chijindu and Boateng, 2008).

Table 1. The average yield and uses of some cassava varieties in Ghana

Variety	Average yield(tons/ha)	Major properties	Major processed products.
Bankyehemaa	27.1	High yielding ; dry matter content (30%); high branching; resistant to CMV*; pinkish red petiole; light green young stem; light brown mature stem; white outer colour of tubers	Flour, gari, fufu, ampesi, agbelima,
Afisiafi	27-30	Yellowish green petiole; green young stem; light brown mature stem; white tubers	*Gari, Agbelima, kokonte*, flour, starch
Tuaka	32.3	High yielding but not resistant to rot and CMV*; medium branching; dark-red petiole colour; deep green young stem; ash matured stem; pink outer colour of tuber	Good for *fufu*, *ampesi*, *agbelima*, *gari*, flour and industrial starch
Duafra	35.6	High yielding and resistant to rot and CMV*; low branching; red petiole colour; light green stem colour; whitish grey mature stem, white tuber colour	Good for *fufu*, *ampesi*, *agbelima*, *gari*, flour and industrial starch
Afram plains	25	Dark green petiole colour; deep green young stem; brown mature stem; pinkish white tubers	Good for *fufu*, *ampesi*, *agbelima*, *gari*, flour and industrial starch
Ankra	36-40	High yielding; resistant to rot and CMV*; low branching red petiole colour; green young stem; greyish white mature stem; pink tubers	Good for *fufu*, *ampesi*, *agbelima*, *gari*, flour and industrial starch

Source: RTIMP, 2006; CSD, 2013

***: Cassava Mosaic Virus**

2.6 CROPPING AND HARVESTING

Annor-Frempong, (1997) observed that, in most cases, farmers plant cassava in well drained soil fields by intercropping with other short seasonal crops such as maize, even though there are differences in the practices of cultivating cassava in Ghana. After harvesting and removal of the crops in fields, the planted cassava is left as monocrop until it matures. The farmers harvest mature cassava bit-by-bit in small quantities in form of "head loads". As such, transporting harvested cassava from farms at afar manually in small head-loads to homes or processing sites in homesteads where processing is usually done contributes to losses as pest continues to attack the remaining cassava on farms (Hahn, 1988). These practices reflect the traditional form of processing cassava in district though there are few commercial processors who can harvest and process large quantities of cassava at a go. Smallholder farmers normally take longer time to harvest and process a hectare of mature cassava than the commercial cassava processors. Also, mechanical damage to produce causes discoloration of the tubers (Gooding, 1987). The damage produced is then carried over to the processing.

2.7 IMPORTANCE AND USES OF CASSAVA

2.7.1 Ecological importance

Apart from cassava serving as the major food security in the world, arbuscular mychorrizal fungi (*Glomus spp.*) are the commonest organisms in symbiotic association with cassava roots. Ecologically, the symbionts supply plant nutrients to the roots in exchange of organic exudates from the cassava root. Usually, the symbionts serve as extension of the cassava root system to plant nutrients beyond the reach of the roots and as a result, provide inorganic soil P (Ceballos *et al*., 2013) and increase cassava yields. The complex network of the mychorriza hyphae in the rhizosphere of crops reduces soil N loss by minimizing leaching (Asghari and Cavagnaro, 2012). It has also been found that mychorriza promotes uptake of K, Ca and Mg by crop plants (Liu *et al*., 2002). Perhaps, mychorriza increase soil moisture contents in the rhizosphere and act as entophytic symbionts to crop roots. In Ghana, farmers hardly apply mineral fertilizers to cassava and/or bother to control soil borne pests because the crop can grow in poor soils and forms a symbiotic association with soil mychorrizal fungi, which can suppress population of plant root feeding nematodes (de la Peña *et al*., 2006) and increase soil organic carbon (Whiffen, 2007). Normally, increased soil fertility status of cassava fields increases yields of subsequent seasonal crops in crop rotation system (Salami and Sangoyomi, 2013).

The root of cassava elongates as it matures and creates a mechanical pressure on the soil structure; loosening of hard soil pans and soil aeration are then promoted especially by cassava with longer root system penetrating deeper into soils. Dakora and Phillips (2002) reported that the organic exudates from roots of plants are mediators that facilitate an increase in plant nutrients in poor soils. The root exudates are responsible for the symbiotic association between the mychorrizal fungi and the root system of cassava (Selvaraj and Chellappa, 2006). The exudates may signal for an increased microbial population in the root zone.

2.7.2 Socio-economic importance of cassava

The crop "cassava" is literally termed by many coastal West Africans in *Ewe* language as *agbeli* meaning "by it life exists" (FAO, 1998). Cassava is an important crop in the Ghanaian economy and accounts for 22% of the national GDP (Sagoe, 2006). Cassava serves as a daily caloric intake of 60% of Ghanaian population making it produced by nearly every household (Sanni, *et al*., 2009). In Suhum Kraboa Coaltar District, cassava is a source of income and is for food security (MoFA, 2009).

2.7.3 Nutritive value of cassava

Cassava roots are rich in carbohydrate (30–35 %), and low in protein (1–2%), fat (< 1%), and some of the minerals and vitamins (Dufuor, 1995). Consequently, cassava roots have lower nutritional value than cereals, legumes and other root and tuber crops. The starch contents of the carbohydrate are 64 to 72% in the form of amylose and amylopectin. The lipid content of cassava is about 0.5% and the essential amino acids particularly lysine, methionine and tryptophan are very low but the peels of roots contain slightly more protein (Smith, 1988) and significant amounts of calcium (50 mg/100g), phosphorous (40 mg/ 100g) and vitamin C (25 mg/100g) and ascorbic acid. The starch is generally digestible. The leaves are richer in protein (23 percent), vitamins and minerals (Dufour, 1995).

2.7.4 Uses of cassava

According to Alhassan (1999), cassava has numerous uses and by-products. Each component is valuable; the leaves are used for stews and the roots for various food kinds (Hahn *et al.*, 1987). In pharmaceuticals, starch is a major source of glucose for medicinal drugs such as tablets, capsules and others. It is also used for the manufacture of mosquito coils. Cassava is also used in the textile, soap and detergent industries. The starchy pastes are used for the manufacture of dry cells. Recently, cassava has been discovered as a potential crop for biofuel (Anonymous, 2010). In Ghana, cassava is normally domestically processed into traditional ethnic-based food kinds such as *fufu, banku, gari, ampesi, konkonte, yakeyake, tuozaafi* and so on (Alhassan, 1999). The leaves are used usually as feed supplements for livestock (Hahn, 1988; Alhassan, 1999; Oppong-Apane, 2013).

2.7.5 Importance of post-harvest management of cassava

Fresh cassava root contains about 65% moisture (Hahn, 1988) making it very bulky after harvest. Carting the fresh cassava to marketing centers is difficult and expensive. As a result, fresh cassava roots after harvest is processed into a form that has better storage characteristics and longevity (Hahn and Keyser, 1985) because fresh cassava can deteriorate rapidly within three to four days. Hahn (1988) also reported that processing of cassava improves quality and extend the shelf life thereby enhancing food security.

The roots and leaves contain varying amounts of cyanide which is toxic to humans and animals, making the raw cassava roots and uncooked leaves unpalatable. Therefore, cassava root and leaves processed into various forms of food kinds in order to increase the shelf life, facilitate transportation for marketing, reduce cyanide content and improve quality for palatability. The nutritional status of cassava can also be improved through fortification with other protein-rich crops such as soya beans (MoFA-WIAD, *2011*). Post-harvest processing reduces food loss and stabilizes seasonal fluctuations in the supply of cassava for food security. According to Oppong-Apane (2013), animal feeds can be made from the bye-products of cassava such as the peels and the residues after sieving the dough during *gari* processing.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study was set up to examine the status of post-harvest management induced production, local cassava processing technique for most common products and alternative process of improving the quality of cassava starch for consumption in the Suhum Kraboa Coaltar District, using a survey of the area and a laboratory assessment of the cassava varieties produced in the area

3.1 DESCRIPTION OF THE STUDY AREA

Figure 3 presents the zones of communities in Suhum Kraboa Coaltar in which the study was carried out. The district is in the Eastern Region of Ghana and is located in a deciduous forest to transition zones with annual rainfall and daily mean temperature of about 1600 mm and 25 °C, respectively. The soils are mainly *Ferric Luvisols* (FAO, 2005). The vegetation is characterized by *chromonella* spp, *panicum* spp, *azadziracta*, *acasia*, big forest trees (*Wawa*, *Emire*, *Odum*, *Iroko*, *Mahogany*, *Ofram* and many more) and perennial cash crops such as cocoa, oil palm, citrus, mango, plantain, pawpaw and banana (SKCD, 2013). Forest covers about 3,370 hectares of land whereas about 44,820 hectares (about 73% of the total arable land) are under cultivation of crops (SKCD, 2013).

The major staple food crops produced in the district are cassava, maize, plantain and cocoyam. But the total area under cultivation of cassava is almost the same as that of maize (SKCD, 2013). Cassava production is mainly rain-fed; major season (March- July) where rainfall is between 900 and 1100 mm and minor season (August to October) where rainfall is about 800 mm.

In the district, the ethnic groups are heterogeneous. The dominating groups are the *Twi* indigenes (35%). Other tribes include the *Ewe* (22.0%), *Krobo/Dangbe* (23.0%), people of Northern Ghanaian tribes such as *Hausa*, *Kontonkoli* and *Basare* (10.0%), *Guans* (5.2%) and *Gas* (4.8%)(SKCD, 2014).

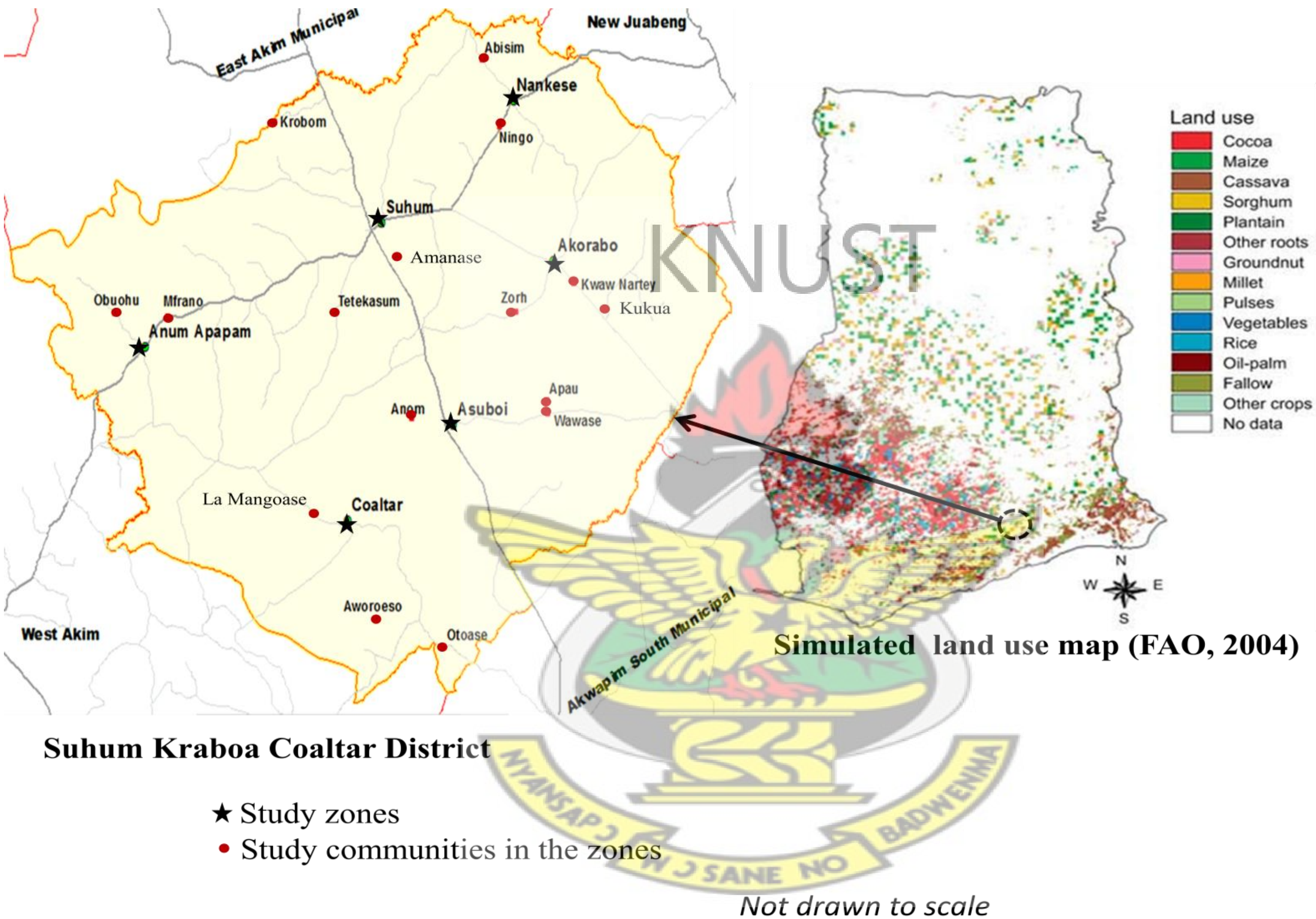

Figure 3. Study zones and communities of Suhum Kraboa Coaltar District in a cassava producing areas of Ghana.

3.2 SURVEY, SAMPLING AND DATA COLLECTION

Questionnaire was used to interview 100 processors and 100 consumers in 6 study zones, namely; Suhum, Akorabo, Asuboi, Coaltar, Anum-Apapam and Nankese. The populations of households in these zones are as shown in **Table 2**. The processors were interviewed on the cassava varieties processed most and the processed products obtained from them. Consumers were interviewed on the most consumed products as well as the quality of product expected. Processors and consumers were randomly selected from randomly chosen communities and interviewed throughout the study zones. Personal communications with people in the communities were also used to obtain additional information such as conditions of farmland acquisition, cultural practices and the stages of processed products. Questionnaires used for the collection of information and data processors and consumers are in appendices 1 and 2.

Data of the national total annual production of the major staple food crops were obtained from the SRID-MoFA database for the period 2000 to 2010. Cassava yield and production for Suhum Kraboa Coaltar District were obtained from the district MIS-MoFA office for the period 2003 to 2013

Table 2. Population of the District based on the six zones

Zones	Population	Households
Nankese	18,925	3,943
Suhum	49,002	10,209
Coaltar	40,502	8,438
Anum Apapam	33,840	7,050
Akorabo	24,414	5,086
Asuboi	22,143	4,613

Source: SKCD (2014)

3.3 ANALYTICAL PROCEDURES

Analysis of some physical and chemical properties (dry matter, starch and pH) of the cassava varieties used in this study were carried out in the laboratory of the Department of Horticulture, University of Science and Technology (KNUST), Kumasi..

3.3.1 *Dry matter content of cassava*

Moisture was determined by drying triplicate of 5 g samples in small metallic containers to constant weight by oven-drying at 105°C (AOAC, 1975).

3.3.2 *Starch content of dry matter*

Cassava samples were sliced and blended with 500 ml of water for five minutes in a blender. The pulp was washed on a sieve with an additional 500 ml of water, and the fibrous material retained on the sieve was thrown away. The washed material was poured into aluminium pans and dried at about 85ºC for 6-12 hours until a constant weight was attained. The weight of the residue represents the percentage of starch calculated from the weight of the sample, (Krochmal and Kilbride, 1966).

3.3.3 *Starch solubility*

One gramme (1g) of cassava powder was mixed with 10mL distilled water in a centrifuge tube and heated in an 85°C water bath for 15 min. The sample was then centrifuged for 15 min at 2,200 rpm. The aliquot was transferred to a pre-weighed beaker and dried at 100°C. Solubility was calculated according to Schoch (1964).

3.3.4 *Water absorption of starch*

Water absorption index were determined by a modification of the methods of Valdez-Niebla *et al*. (1993), Ju and Mittal (1995) and Subrahmanyam and Hoseney (1995). This was a centrifugal procedure. Starch samples (1 g) were suspended in 5 mL water in a centrifuge tube. The slurry was shaken on a platform tube rocker for 1 min at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was poured carefully into a tarred evaporating dish.

3.3.5 *pH and quantification of gari and tapioca*

Tubers of four cassava varieties (*Afisiafi*, *Ankra*, *Duafra* and *Tuaka*) were obtained from farms of farmers in the district. The tubers (roots) were peeled into bowls according to the *gari* processing techniques and then labelled separately. The peels were discarded. The peeled tubers were weighed and recorded for each variety and then grated into cassava dough (*agbelima*). Distilled water was added adequately to dissolve soluble starch for collection. The mixture (dough +water) was put into clean sacks (the type used by *gari* processors) and pressed under a metal presser and the starch suspension was collected into clean plastic buckets.

The starch suspension was allowed to settle over-night and the supernatant was decanted into another plastic buckets, stirred thoroughly and 25 mls of it taken separately for each cassava variety. According to the method used by Miller and Kissel (2009), the pH was measured by inserting the electrode of the pH meter into the 25 mls of the supernatant from cassava variety.

The sediment (the soluble starch) was air-dried in hot sun for two days according to the local *tapioca* processing, crushed into smoother form and then roasted in hot pan on fire into *tapioca*. The weight of the *tapioca* obtained for each cassava variety was determined on an electronic scale and recorded. Also, the pressed dough was sieved according to the local *gari* processing and the fine textured one was roasted on fire into *gari* after discarding the coarse fibrous materials on the sieve; the weight of the *gari* for each variety was recorded.

3.3.6: Sensory evaluation for acceptability of quality

Sensory evaluation was conducted to estimate the acceptability of the quality of food kinds made from *gari* and *tapioca*. The food kinds, namely; 100g of raw *gari*, 100g of raw *tapioca, eba (100 g of gari), eba (100 g of tapioca), eba (tapioca:gari)*$_{1:3}$, soakings*(100 g of gari),* soakings *(100 g of tapioca)* and soakings *(tapioca:gari)*$_{1:3}$ were prepared by using the *gari* and the *tapioca* obtained from the four varieties. Three grammes (3) each of sugar and milk powder was added to maintain taste of sugar and milk in a normal soakings. Also, to maintain taste of salt in *eba*, 2 g of table salt was added to about 150 mls of hot water for the *eba*. Fifty-five (55) member panelists was allowed to eat and taste the quality of the food kinds and assign scores of 1 to 7 according to the 7-point hedonic scale (**Table 3**) of Ihekoronye and Ngoddy (1985) and Chinma and Gernah (2007). The score sheets were collected and analyzed.

Table 3. The 7-point hedonic scores used for the acceptability of quality of products

Scale score	Interpretation to acceptability of quality
1	Liked very much
2	Liked much
3	Liked
4	Neither liked nor disliked
5	Disliked
6	Disliked much
7	Disliked very much

Source: Ihekoronye and Ngoddy (1985); Chinma and Gernah (2007).

3.4 DATA ANALYSIS

The weights of the *tapioca* and *gari* were converted into percentages over the weight of the peeled cassava for each variety. The *gari*:*tapioca* ratio was determined.

The Minitab 14.0 was used to calculate standard error and LSD (P= 0.05) to separate means. Descriptive statistics such as percentages were estimated for relevant variables. Graphs and distribution tables were used to present the data.

CHAPTER FOUR

4.0. RESULTS

4.1. CONTRIBUTION OF CASSAVA PRODUCTION IN THE DISTRICT

Among the eight major staple food crops produced by farmers in Ghana, cassava production dominates in both Suhum Kraboa Coaltar District and at the national level (**Figure 4**). At the national level, average proportion of cassava production was 50% annually and that of Suhum Kraboa Coaltar District was about 76% annually. This was followed by production of yam at the national level (20%) and plantain in the Suhum Kraboa Coaltar District (SKCD) (12.6 %). There was no significant difference in the proportions of plantain productions both in SKCD and at the national level even though it was the second and third stable crop in SKCD and at the national level, respectively. Maize was the third staple crop in SKCD. However, maize and cocoyam were relatively the fourth staple crops in Ghana. Contribution of both yam and cocoyam productions in the SKCD was collectively less than 1%. There were no rice (paddy), millet and sorghum productions in SKCD but these crops were collectively about 3% of the total national staple food crop production.

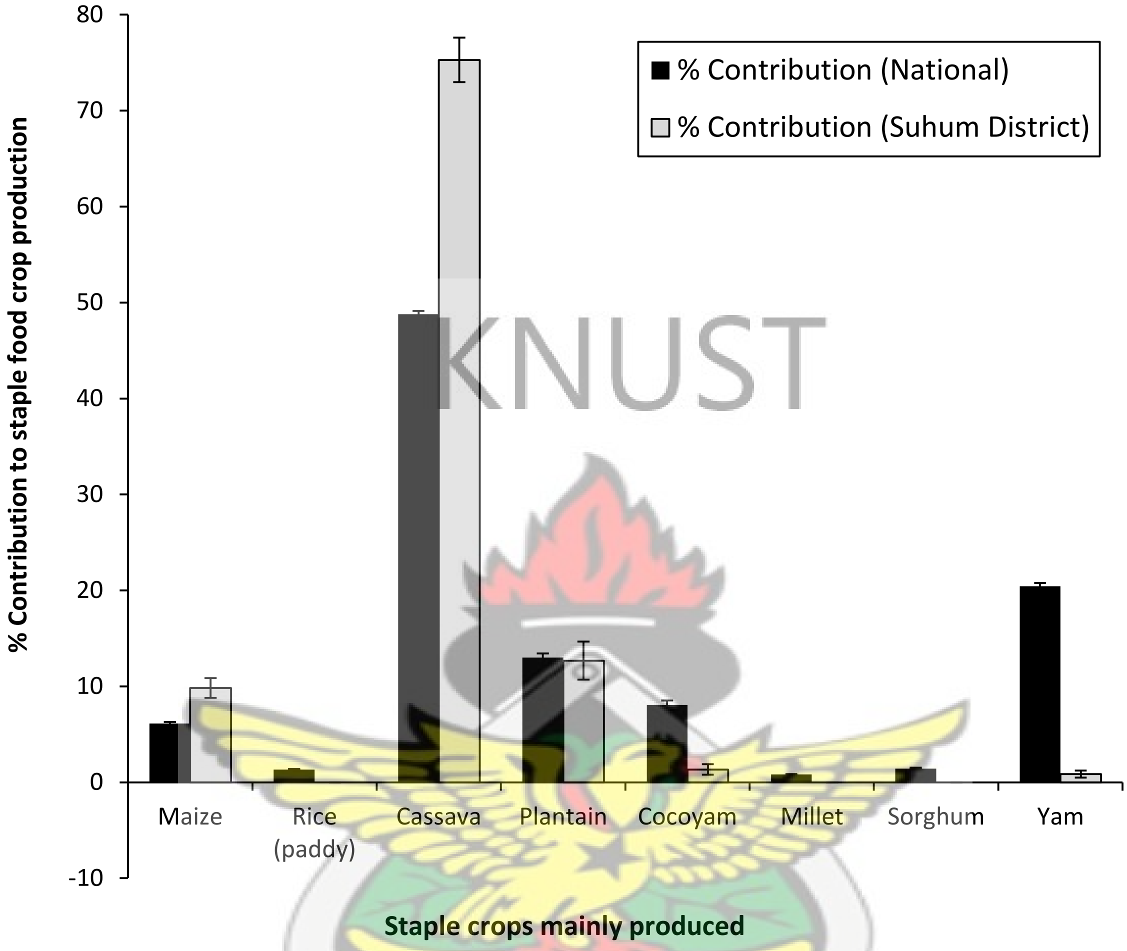

Figure 4. Annual contributions of crops to the major staple food crop production: national and Suhum District data

Figure 5 presents the patterns of cassava production and yield indices for the district. In SKCD, cassava production indices increased with increasing yield indices and decreased with decreasing yield indices between the years 2005 and 2013. Cassava production index gradually decreased to a minimum 0.6 in 2005 (base production year = 2003). It then increased to a maximum 2.3 in 2007. There was a sharp decrease in the index for SKCD between 2007 and 2008 to a minimum 0.7 (production index in 2007) from where it again increased to a peak of 1.7 in 2010. From 2010, gradual decline in the production index was observed. The maximum cassava yield indices were observed in 2004 (about 2.8), in 2007 (about 3.1) and in 2010 (about 2.9); the peaks were relatively the same (about 3.0). The lowest cassava yield index was observed in 2008 (about 1.2, base year = 2003). From 2005, cassava yield index of SKCD increased and decreased with increase and decease in cassava production index of SKCD. The declining phase of both indices started from the year 2010. But both the yield and production indices for the national data had an increasing phase from 2006 (base year = 2000).

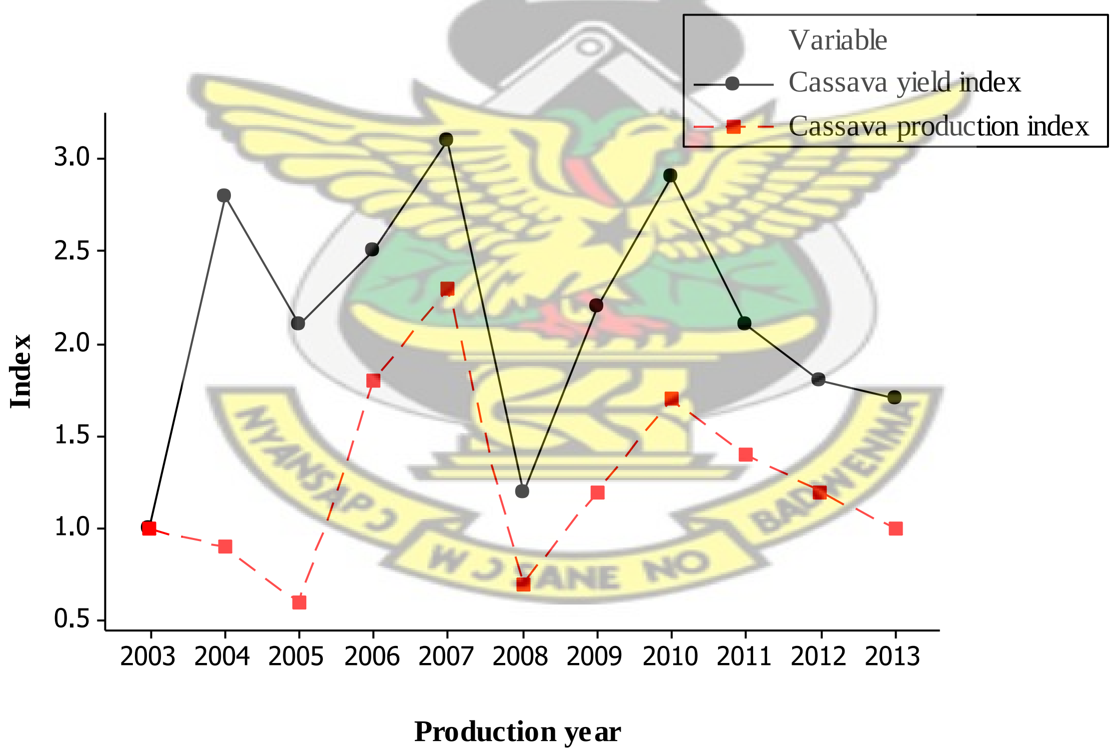

Figure 5. Production and yield indices of cassava in the Suhum Kraboa Coaltar District (SKCD)

4.1.1 Properties of cassava produce

Table 4 Presents some selected physico-chemical properties of mature produce from four varieties. Among the produce of the mature varieties tested, *Afisiafi* had the lowest pH value (4.5). *Tuaka*, *Ankra* and *Duafra* had pH values above 5.0. The starch content of *Duafra* was higher than that of *Tuaka*, *Ankra* and *Afisiafi*. Similarly, the *Duafra* and *Tuaka* had higher dry matter content than that of *Afisiafi* and *Ankra*. But the solubility of starch from *Duafra* was twice that of *Ankra*. *Afisiafi* and *Ankra* had lower starch solubility. There was no significant difference (P = 0.05) in the water absorption ability of the dry matter from the four varieties.

Table 4. Some selected properties of mature cassava produce from four different varieties

Variety	pH (supernatant)	% Starch	% Dry Matter	**% solubility**	Water Absorption
Ankrah	5.4	32.0	33.2	2.4	1.6
Afisiafi	4.5	28.0	32.6	1.6	1.7
Tuaka	5.1	28.0	36.0	2.0	1.5
Duafra	5.6	38.0	38.6	4.8	1.4
LSD (p<0.05)	0.03	1.88	3.76	0.56	0.19

LSD: least significant difference at significant level p<0.05

4.2 POST-HARVEST MANAGEMENT OF CASSAVA

4.2.1 Experience, trainings and adoptions

Cassava processors have about 21 years of experience in processing (**Table 5**). But about 85% of processors did not have formal education above the basic level but rather had not education (13%) or basic level education (72%). No interviewed processor had education up to the tertiary level. Thirteen percent (13%) of producers interviewed did not have any formal education. Majority of the processors interviewed were largely trained by the RTIMP/MoFA and NGOs. No processor interviewed had been trained by the Research Institutes or banks. But adoption of training innovations by processors was low; 48% of the farmers indicated that they adopted innovation once annually whereas 61% of processors adopted innovations once every 3 years.

Table 5. Factors affecting the skills of processors

	Education				Source of trainings				Adoptions of trainings			
Average years of experience	Not educated	Basic	Secondary	Tertiary	RTIMP/MoFA	NGOs	Ris	Banks	In 1 year	In 2 years	In 3 years	In >3 years
20.8 ± 1.5	13%	72%	15%	0%	80%	20%	0%	0%	9%	6%	61%	23%

Ris: Research institutes,

RTIMP/MOFA: Root and Tubers Improvement by Ministry of Food and Agriculture

NGOs: non-Governmental Organisations

4.2.2 Sufficiency, processing and handling

In **Figure 6,** the proportion of processors both commercial and individual consumers) processing cassava produced in the study district was about 92%. Comparing processing of cassava into products, the individual consumer processing fufu was 96%, which was more than the commercial *fufu* processors 11%) (**Table 6**). *Agbelima* and *gari* processors were more commercial (63% and 81%, respectively) than the individual consumers that processed them for consumption. But the individual consumers that processed cassava into dry chips/*kokonte* were three times more the commercial processors of the same product. Commercial processors of animal feeds, starch and other products were 0%, 7% and 9%, respectively.

In terms of consuming commercially processed products, the consumers of dry chips/*kokonte*, *gari*, *agbelima* and *fufu*, were 37%, 76%, 81% and 89%, respectively. Generally, consumers of *fufu* (both commercial and individual) were higher than all other products.

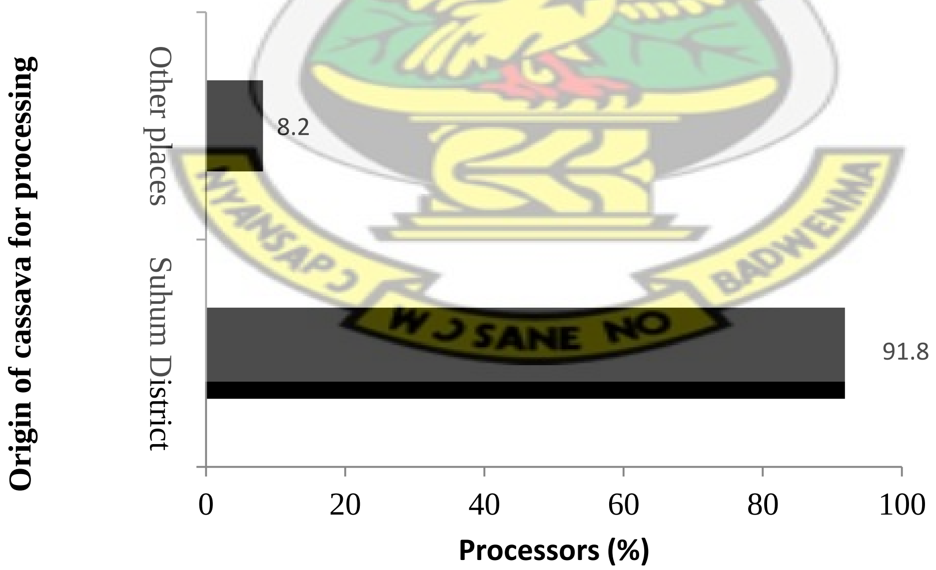

Figure 6. The major source of cassava for processing in the district.

Table 6. Proportion of processors and consumers for the cassava products available in the districts

Groups	Processed cassava products						
	fufu	*agbelima*	*gari*	Starch**	dry chips/*kokonte*	animal feeds	others
Commercial processing for sale							
Processors	11%	63%	83%	7%	24%	0%	9%
Consumption*							
Individual (private) consumers processing	96%	37%	17%	3%	76%	5%	5%
Consumers of commercially processed products	89%	81%	76%	46%	37%	12%	29%

*: Consumers do private processing for consumptions and, at times, patronize commercially processed products;

**: starch is used for *tapioca* in Suhum District.

Processors graded products before packaging. The products were adulterated with soyabeans, colour, etc. These treatments are normally for attractiveness, taste, fine texture, high price and nutritive value. In **Table 7**, 75% and 83% of the interviewed processors stated that both additions of additives to products were for high price and nutritive value, respectively. The proportion of the processors that would want to add additives for attractiveness of products is 7%. But processors adding additives for the purpose of taste and fine texture were 5% and 10%, respectively. Forty-four percent (44%) and 81% of the processors confirmed that grading for and attractive appearance and high marketing prices of the products. The packaging types available in the district were not really for high price, taste, fine texture and nutritive value but for improvement in appearance of products.

Table 7. Purposes of improving nutritive value and packaging cassava products

Purpose	Value addition for marketing		Packaging types		
	Adding additives	Grading	In polythene	In bowls	In sacks
High price	75%	81%	4%	2%	0%
Attractiveness	17%	44%	16%	12%	0%
Taste	10%	0%	0%	0%	0%
Fine texture	5%	0%	0%	0%	0%
Nutritive value	83%	0%	0%	0%	0%

4.3 POST-HARVEST PROCESSING INTO *TAPIOCA* AND G*ARI.*

Figure 7 describes all the cassava processing pathways used by both small and large scale processors in the district. **Figure 8** compares the yields of *gari* and *tapioca* (from soluble starch) obtained from processing the different cassava varieties. Among the varieties, the *Duafra* gave the highest yields of both *gari* (about 27%) and *tapioca* (about 4%). The lowest amount of *tapioca* (2%) was obtained from *Ankra*. There was no significant difference in the amount of *tapioca* from the *Afisiafi, Tuaka* and *Duafra.* The quantity of *gari* obtained from the four varieties ranged from 21% to 27% of the total weight of peeled fresh cassava. However, processing *tapioca* from the varieties increased the total yields of both *gari* and *tapioca* combined by 3.5%; the highest yields of the products combined were obtained from *Duafra*.

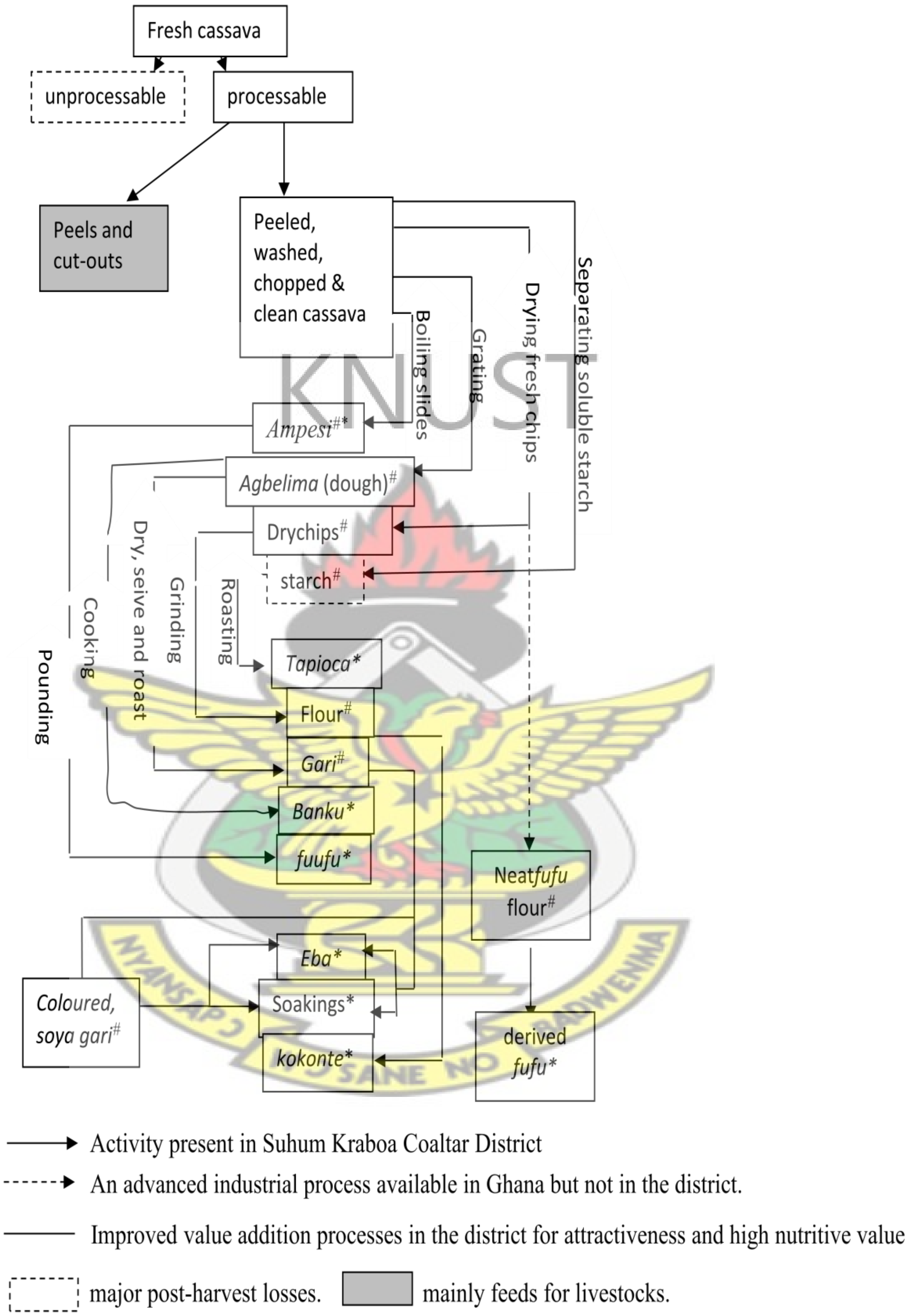

Figure 7. The commonest cassava processing activities and processed products present in the Suhum Kraboa Coaltar District. #: intermediate; *: eaten as finished.

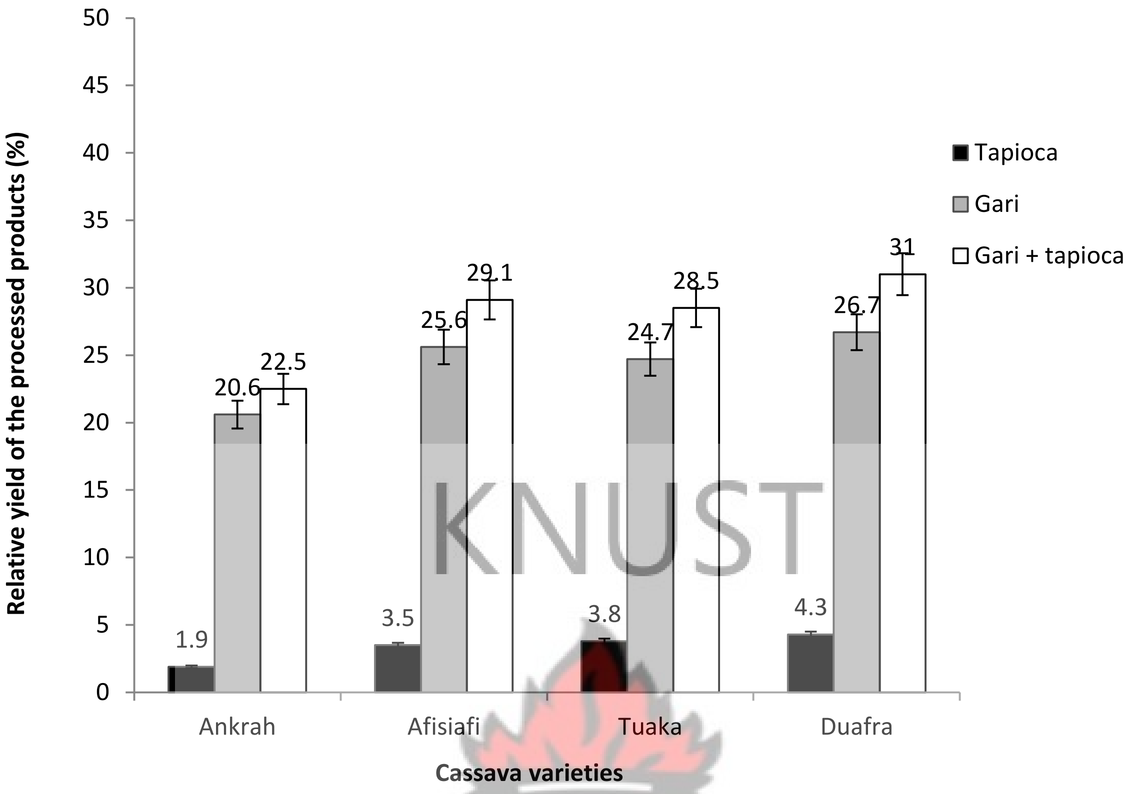

Figure 8. Comparison of *gari* and *tapioca* obtained from roots of mature cassava varieties.

4.4. QUALITY, PREFERENCE AND PACKAGING OF DIFFERENT FOOD PRODUCTS FROM *GARI* AND *TAPIOCA*

In **Table 9**, the lower the score value, the more acceptable the quality of the food kinds made from *tapioca* and *gari*. There was no significant difference between the mean sensory scale scores for raw *gari* and that of the *raw tapioca*. But the *eba* (*gari*) had higher mean score of 3.5±0.3 than the soakings (*gari*). Though the different food products from soakings had low mean scores there was no significant difference in the mean scores. The highest mean sensory scores for the acceptability of quality were observed for *eba* (*tapioca:gari*)$_{1:3}$ and *eba* (*tapioca*) as 5.0±0.4 and 6.5±0.3, respectively. This confirms that processed products from different cassava varieties have varying quality and therefore, have different consumer preference levels. (**Table 9)**. However, the packaging of the various products depends on the acceptability of the materials used (**Table 10)**

Table 8. Estimated quality acceptability for the different food products from *gari* and *tapioca*. Scores assigned by the largest proportion of panellists were selected and recorded. In bracket, are the percentages of panellists assigning scores.

	Raw		*eba**			Soakings		
	Gari	*tapioca*	*Gari*	*tapioca*	(*tapioca*:*gari*)$_{1:3}$	*gari*	*tapioca*	(*tapioca*:*gari*)$_{1:3}$
Ankra	3 (92%)	2(97%)	3(100%)	6(97%)	4(81%)	3(100%)	2(100%)	2(91%)
Duafra	2 (85%)	3(93%)	4(95%)	7(85%)	6(93%)	3(93%)	2(100%)	2(83%)
Afisiafi	3(92%)	3(91%)	4(100%)	7(92%)	5(87%)	2(99%)	3(93%)	3(87%)
Tuaka	2(88%)	3(88%)	3(98%)	6(88%)	5(85%)	2(89%)	3(87%)	2(96%)
Mean ± se	**2.5±0.3**	**2.8±0.3**	**3.5± 0.3**	**6.5± 0.3**	**5.0±0.4**	**2.5±0.3**	**2.5±0.3**	**2.3±0.3**

se: standard error;

*: a literal abbreviation of "***E**nergy **B**efore **A**bility*";

Interpretations of hedonic scale scores 1-7 are in **Table 3**;

Mixture of *tapioca* and *gari* is in ratio 1:3.

Table 9. Consumer preference level for the possible cassava products from the various varieties

Cassava variety	*Fufu*	*Agbelima*	*Gari*	*Kokonte*	*tapioca*[#]	*ampesi*	*Kaklo*	*yakeyake*
Ankra	***	***	***	***	**	***	***	**
Afisiafi	*	****	****	***	**	*	**	***
Tuaka	****	***	***	***	**	***	**	***
Duafra	**	***	***	***	**	**	***	***
Afram plains	****	***	***	***	***	***	***	***
Bankyehema	***	***	***	***	**	****	***	***
Ningo	***	***	***	**	**	****	***	***

*: low (<25%); **: high (25-50%); ***: very high (51-75%); ****: extremely high (>75%)

#: Processed products from starch.

Table 10. Shelf-life and status of packaging types available for marketing processed products

	Processed cassava products				
Packaging material	*Fufu*	*Agbelima*	*Gari*	Starch	dry chips/Kokonte
Polythene bags	*	***	***	***	***
Bowls	***	**	**	**	**
Sacks	n.a	**	**	**	**
Shelf-life (range)	< 1 day	3-10 days	2 years	<3 months	< 6 months

n.a: not applicable; *: unacceptable; **: good; ***: very good

CHAPTER FIVE

5.0 DISCUSSION

5.1 EFFECT OF POST-HARVEST PROCESSING ON CASSAVA PRODUCTION PATTERN

The production index of cassava as a staple food crop had indicated that the trend of cassava production is not consistent in the study district (**Figure 3**). The annual output level had been observed as high in some years and low in other years. Production was extremely high in 2006. This can be attributed to the fact there were intensive farmer training programmes on rapid multiplication of planting materials (RTIMP, 2006) and improving yields of root and tubers. *Gari* processing factory was also set up in the same year, which might have promoted high production of cassava in 2007. The collapse of the factory as a result of small size of market for the products consequently could have caused the sharp drop in cassava production level in 2008. However, the revival of the factory again increased production index in 2010 to a maximum peak of about 2.9. Since then, the factory became technically unoperational leading to a continuous decline (from 2010) in cassava production in the district. It was also possible that the cassava varieties the farmers were cultivating then for supply to the factory were not suitable for the major consumable processed products such as *fufu* at household level. This effect could change the farmers' attitude from planting high yielding industrial varieties to low yielding types suitable for commonest products such as *fufu.* It was apparent that the falling trend in cassava production since 2010 could have resulted in a localized food crisis in the Suhum District. When there is higher demand for food stuffs than what the system can supply, there was always crisis with high food prices (Sumanjeet, 2009).

5.2 FACTORS AFFECTING POST-HARVEST MANAGEMENT OF CASSAVA IN THE DISTRICT

A large number of processors indicated that they depended on supply of cassava from Suhum District for processing. This suggests that the quantity of cassava produced in the district was sufficient enough to meet the demand of the processors (**Figure 6)**. The results also suggest that for an industrial set-up, it was more economically viable to site factories close to the source of the raw materials since the cost of carting raw materials was reduced. Cassava varieties grown in the district seem to have high dry matter (32.6% to 38.6%)(**Table 4**) that give high yields of processed products (**Figure 8**). Also, consumer preference varies for products from different varieties; consumers have high preference for *fufu* processed from *Tuaka* and *Afram plains* (**Table 9**). Using *Afisiafi* for *fufu* and *ampesi* will likely attract less than 25% of consumers because the variety was not suitable. Products of some varieties may have bitter tastes. Such varieties are used mainly for *gari*, *agbelima* and *kokonte.* Hence, the selection of the suitable varieties depended on the processed product type.

Addition of additives such as soyabeans and palm oil improves, to some extent, the nutritive value, attractive appearance, taste and fine texture. These were generally the features the consumers were looking for. High prices offered to products containing additives were likely to make processors continue in the processing of high quality products.

The packaging types common in the district were the polythene bags, bowls and sacks (**Table 10**). These were not expensive and majority of the consumers were satisfied with them. Usually, the packaging depends on the processed product types. For example, *fufu* cannot be packaged in sacks but were more preferably heaped in a ceramic bowl locally known as *asanka*. Consumers are more attracted to *fufu* with hot soup in *asan*ka. Polythene and sacks were suitable for *gari*, *agbelima* and dry chips or *kokonte* and high quality cassava flour. The later was not common in the district. Therefore, appropriate packaging materials used by processors for the various products also keep them in processing business.

The processors have many years of experience and that they will keep doing the appropriate and acceptable practices. Training processors may not be a factor that will promote processing because adoption period is too long (about 3 years for majority of processors) and the technology can be misconstrued. Possibly, the trainings received by these processors might involve a more expensive and complex techniques requiring special facilities. For example, the WIAD –MoFA trained processors in 2009 on how to produce HQCF (High Quality Cassava Flour). However, this product was not in the district because the process requires an expensive galvanized machines and technical procedures.

5.3. POST-HARVEST *GARI* PROCESSING INDUCED STARCH LOSSES

The processing stages, which represent the normal practices, can be related to the product types, namely: primary, intermediates and finished (**Figure 7**). Cassava was firstly peeled and washed thoroughly to remove dirt and soil particles. Depending on the target primary processed product, it was either grated into cassava dough (*Agbelima*) (Oti *et al*., 2010) or chopped into pieces or chips for further processing. *Gari* was obtained from cassava dough (*Agbelima)*. Red oil or milled soyabeans flour was sometime added to the *gari* during roasting.

In this study, it was observed that 83% of commercial processors process cassava into *gari* because *gari* has long shelf-life (2 years) and easy to package for storage. Post-harvest processing of cassava into *gari* involved the removal of peels and cut-outs, which can be used as animal feeds (Oppong-Apane, 2013) from raw cassava. It was then grated into dough (*agbelima*) to which water was added adequately and pressed to remove the cyanic acids. The suspensions from the pressed dough contain soluble starch. The pressed dough was sieved and the fine textured one is roasted into *gari*. The current study indicated that post-harvest processing of the soluble starch into *tapioca* will keep the *gari*:*tapioca* ratio at **8:1** suggesting that post-harvest processing of soluble starch will give the quantity of *tapioca* to be ideally one-eighth of that of *gari*.

Unfortunately, the proportion of starch processors interviewed was very low even though there were 46% of consumers interviewed available for the consumption of the starch; consumer preference for *tapioca* from starch was high (25-50%). Cassava is completely starchy and starch has many uses (Setyawaty *et al*., 2011; Gunorubon, 2012) but processors do not extract starch as one of the main products. The cultural practice during the post-harvest management of cassava into *gari* involves draining and discarding the starch suspensions from cassava dough as wastes (Obeng, 2012). Largely, the *Twi* indigenes are not known for eating *tapioca* and hence, commercial processing of starch into derivative products was not observed in the district.

5.4. IMPROVING THE QUALITY OF *TAPIOCA* IN *GARI*

In 2007, the RTIMP of MoFA trained farmers and the processors on the alternative strategies of maximizing the uses of cassava and the processed products. The project was to minimize post-harvest losses during processing of cassava. However, it was obviously clear in this study that processors did not adopt the technologies from the trainings in order to increase cassava utilization for maximum food security. In Ghana, adoption of new agriculturally related innovations was generally low (Owusu *et el,* 2012; Bellwood-Howard, 2013). As such, cassava processing was limited to 4 major products, namely, *fufu, agbelima, gari* and *kokonte* (**Table 6**) due to the diverse ethnic groups present in the district. For example, the

Ewes and other smaller groups are associated with using *agbelima* for *banku* whereas the *Twi* indigenes are noted for eating *fufu.*

It was significant that research investigations detail on the exploration of alternative uses of cassava before training stakeholders in the Suhum District in order to increase use of processed products such as *tapioca* and *gari* because of their long shelf-life. However, the acceptability of quality of the different food products from *tapioca* and *gari* must be assessed. In this study, the analysis indicated that the quality of all 'soakings' from *tapioca* and/or *gari* was more accepted than all the "*eba"* from *gari* and *tapioca*. In the Suhum District, people generally like eating more soakings than *eba* because it was faster to prepare soakings than to prepare *eba*. Also, the *eba* made from *tapioca* is completely disliked though the term "*eba*" stands literally for "*E*nergy *B*efore *A*bility" and that *tapioca* had high energy content, but, because of its sliminess and stickiness, it was usually not accepted for making quality *eba* food kinds.

Surprisingly, soakings from combination of *tapioca* and *gari* had high quality acceptability but this food kind was not available in the district. Comparing the acceptability of soakings (*tapioca*) to soakings (*tapioca* and *gari*), the later was more accepted. This was because consumers for *tapioca* was low (about 49%) (**Table 6**) with consumer preference level between 25 and 50% (**Table 9)**. Therefore, processing and packaging new cassava products (a mixture of *tapioca* and *gari*) available in the district, would receive such as high quality acceptability for soakings because the *gari* content of the mixture had very high consumer preference and was largely processed and consumed by many people. By so doing, starch suspensions generally discarded during *gari* processing would then be given a value in this form to prevent post-harvest losses in the district.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1. CONCLUSION

In this study, disfunctioning cassava processing amenities in Suhum Kraboa Coaltar District is causing a continuous decrease in the annual cassava production, which can likely cause a localised food crisis in subsequent year(s). the results indicate that, post-harvest processing of cassava mainly depends on the availability of cassava in the district, many years of experience of processors, acceptability of simple packaging and high consumer preference for ethnic-based products. The quantity of *tapioca* from starch suspensions, usually discarded during *gari* processing, was found to be one-eighth of the weight of *gari*. The new products (soakings of a mixture of *tapioca* and *gari*) have higher quality acceptability than *eba* from *tapioca* and/or *gari*.

6.2 RECOMMENDATIONS

This study suggests that:

1. Post-harvest processing facilities are revamped to increase annual cassava production in the subsequent years.
2. Instead of discarding the soluble starch suspensions during *gari* processing, *gari* processors should process and package new products (mixture *tapioca* and *gari*) for highly acceptable quality soakings in order to reduce post-harvest loss of the starch.

REFERENCE

Aboagyewaa, J., (2011). Cassava processor, Amanase. *Personal communication*

Adu-Mensah, J., Owusu-Akyaw, M. and Mochiah, M. B. 2007. Insect Pests of Dried Cassava (*Kokonte*) in Ashanti and Brong Ahafo Regions of Ghana. Journal of the Ghana Science Association 9 (2), 9-17.

Alhassan, R. M. (1999). Cassava as a food security crop in Ghana: A characterisation of village level processing and marketing. First National Workshop on Root, Tubers, Kumasi, Ghana. COSCA study paper

Annor-Frimpong, F. K. (1997). Farmers, extension agents and researchers' perception and participation in maize technology development in Ashanti Region of Ghana. *M.phil thesis*, Department of Agricultural Economics and Extension, University of Cape coast, Cape Coast.

Anonymous. (2010). Global Consultation Workshop on Cassava as a Potential Bioenergy Crop, Accra 18-19 October, 2010.

AOAC (Association of Official Analytical Chemists). (1975). Official methods of analysis. 12th ed. Washington D.C.

Asghari, H. R. and Cavagnaro, T. R. (2012). Arbuscular mycorrhizas reduce nitrogen loss via leaching. PLoS One. 7(1): e29825.

Banito, A., Kpémoua, K.E., Bissang, B. and Wydra, K. (2010). Assessment of cassava root and stem rots in ecozones of Togo and evaluation of the pathogen virulence. Pakistan Journal Botany 42(3), 2059-2068

Bellwood-Howard, I. (2013). Compost adoption in Northern Ghana. International Journal of Sustainable Development & World Policy, 2(2), 15-32

Bradbury, J. H., Holloway, W. D. (1988). Chemistry of Tropical Root Crops: Significance for Nutrition and Agriculture in the Pacific. Australian Centre for International Agricultural Research, Monograph No. 6, Canberra, Australia

Cardoso, P. A., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, R. M. and Howard B., J. (2005). Processing of cassava roots to remove cyanogens. Journal of Food Composition and analysis 18 451–460

Ceballos, I., Ruiz, M., Fernández, C., Peña, R. and Rodríguez, A. (2013). The In Vitro Mass-Produced Model Mycorrhizal Fungus, *Rhizophagus irregularis*, Significantly Increases Yields of the Globally Important Food Security Crop Cassava. PLoS ONE 8(8): e70633. doi:10.1371/journal.pone.0070633

Chijindu, E.N. and Boateng, B.A. (2008). Effect of Nutritional Content of Processed Cassava Chips on Development of *Prostephanus truncates* (Horn).World Journal of Agricultural Science 4 (3), 404-408.

Chinma, C. E. and Gernah, D. I. (2007). Physicochemical and sensory properties of cookies produced from cassava / soyabean / mango composite flours. Journal of Food Technology, 5: 256-260.

Cocks, J. H. (1985). Cassava: New Potential for a Neglected Crop. Boulder, Colo., and London: Westview Press, Collinson, V. D., Gallet, G. and Westby, A. (2001). Urban market opportunities for high quality cassava products in Ghana.Natural Resources Institute, University of Greenwich, Central Avenue, Chatham, Kent ME4 4TB, United Kingdom.

CSD. (2013). Cassava varieties released in Ghana. Crop Services Directorate, Ministry of Food and Agriculture, Ghana.Unpublised.

Dakora, F. D. and Phillips, D. A. (2002). Root exudates as mediators of mineral acquisition in low-nutrient environments. Plant and Soil 245, 35–47

de la Peña, E.,, Rodríguez E. S., van der Putten, W, H. Freitas, H. Moens, M. (2005). Mechanism of control of root-feeding nematodes by mycorrhizal fungi in the dune grass Ammophila arenaria. New Phytologist 169, 829–840

Doku, E. V. (1999). Cultivated cassava varieties in Ghana. Ghana Journal of Science 6 (3-4), 74-86

Dufour, D. L. (1994). Cassava in Amazonia: Lessons in Safety and Utilization from Native Peoples. *Acta* Horticulturae 375:175–182.

Dufour, D. L. (1995). A Closer Look at the Nutritional Implications of Bitter Cassava Use." In Indigenous Peoples and the Future of Amazonia: An Ecological Anthropology of an Endangered World. Edited by Leslie E. Sponsel. Tucson: University of Arizona Press,

Egyir, S. and Obeng, O. (2008). Harvest and post harvest baseline study. Policy, Planning, Monitoring and Evaluation Directorate Ministry of Food and Agriculture, Ghana.

Eke-okoro, O. N. and Njoku, D. N. (2012). A review of cassava development in Nigeria from 1940-2010. ARPN Journal of Agricultural and Biological Science 7(1), 59-65.

FAO. (1998). Post-harvest loss due to pests in dried cassava chips and comparative methods for its assessment: A case study on small-scale farm household in Ghana. Rome, Italy.

FAO. (2005). Fertilizer use by crop in Ghana. Vialedelle Terme di Caracalla, Rome, Italy.

Gnonlonfin, G. J B., Hell, K., Siame, A. B. and Fandohan P. (2008). Infestation and Population Dynamics of Insects on Stored Cassava and Yams Chips in Benin, West Africa. Journal of Economic Entomology 101(6), 1967-1973.

Gonzalez, C., Johnson, N. (2009). Consumer preference for table cassava characteristics in Pernamburo, Brazil. *Revista de economia e agronegócio, vol.7, no 3*

Gooding, E. G. B. (1987). *Crop and Product Digest No 2-Root Crops*, Second Edition. London: Tropical development and Research Institute

Gunorubon, A. J. (2012). Production of cassava starch-based adhesive. Research journal in engineering and applied sciences 1(4), 219-214.

Hahn, S. K. (1988). An overview of traditional processing and utilization of cassava in Africa: Proceedings of the IITA/ILCA/University of Ibadan Workshop on the Potential Utilization of cassava as Livestockfeed in Africa. 14-18, Ibadan Nigeria.

Hahn, S.K, and Keyser.J. (1985).*Cassava: a basic food of Africa. Outlook on Agriculture* 4: 95-100.

Hahn, S.K., N.M. Mahungu, J.A Otoo, M.A M. Msabaha, N.B. Lutaladio, and M.T. Dahniya.(1987). Cassava end African food crisis. Pages 24-29 in Tropical root crops -root crops and the African food crisis. Proceedings, Third Triennial Symposium of the International Society for tropical Root Crops - Africa Branch, edited by E.R Terry, M. Akoroda, and O. B. Arene, 17-23 August 1986, Owerri, Nigeria.

Hillocks, R. (2002). Cassava In Africa. In R. Hillocks, J. Thresh, & A. C. Bellotti, eds., Cassava Biology, Production and Utilization. CABI Publishing.

Hillocks, R..J. (2001). Cassava In Africa. Natural Resources Institute, University of Greenwich, Central Avenue, Chatham, Kent ME4 4TB, United Kingdom.

Ihekoronye, A. I. and Ngoddy, P. O. (1985). Integrated Food Science and Technology for the Tropics. Macmillan Publishers, London, UK.

Ju, J. and Mittal, G.S, (1995). Physical properties of various starch based fat-substitutes. *J. Food Processing and Preservation* 19:361-383.

King, N.L.R., and Bradbury, J.H., (1995). Bitterness of cassava: identification of a new apiosyl glucoside and other compounds that affect its bitter taste. Journal of the Science of Food and Agriculture 68, 223–230.

Krochmal. J, and Kilbride. M.(1966), An inexpensive laboratory method for cassava starch extraction. University of Puerto Rico, Jour Agriculture 50(3). 252-253.

Liu, A., Hamel, C., Elm, A., Costa, C., Ma, B. and Smith, D.L. (2002). Concentrations of K, Ca and Mg in maize colonized by arbuscular mycorrhizal fungi under field conditions. Canadian Journal of Soil Science 82(3), 272-278

Miller, R. O. and Kissel, D. E. (2009). Comparison of Soil pH Methods on Soils of North America. Soil Sci. Soc. Am. J. 74:310–316. DOI:10.2136/sssaj2008.0047

MoFA, (1997). Weekly Market Price Information, January to December, Credit and Marketing Service Division, Ministry of Agriculture

MoFA, (2009). Facts and Figure, Agriculture in Ghana, Accra, Ghana,

MoFA- WIAD, Suhum. (2011). *Personal communication*

Nweke, F.N. Offer, E.C. and Okaka, A.N.C. (1992). Africa Journal on Agriculture, Lagos, Nigeria

Obeng, E. (2012). Gari Processors Association, Oko-Nkwanta. *Personal communication.*

Okogbenin, E., Egesi, C., Fregene, M. (2006). Marker Aided Introgression of CMD Resistance in Latin American Germplasm for the broadening of the Genetic base of cassava in Nigeria. NRCRI, Umudike Annual Report 2006, 2-6

Oppong-Apane, K. (2013). Cassava as animal feed in Ghana: Past, present and future. FAO, Accra, Ghana.

Oti, E., Olapeju, O., Dohou, S., Moutairou, E., Nankagninou, D., Komlaga, G.A. and Loueke, G.M. (2010). Processing of cassava into gari and high quality cassava flour in West Africa. Training manual (draft). USAID/CORAF/SONGHAI.

Owusu, V. and Donkor, E. (2012). Adoption of improved cassava varieties in Ghana. *AgriculturalJournal* 7 (2): 146-151.

Phillips, T.,D. S.Taylor, L.Sani, and M.Akoroda.(2004) *A Cassava Industrial Revolution in Nigeria. The potential for a new indusrial crop.*pp 43.IFAD/FAO, Rome.

RTIMP. (2006). Regional Initiative Workshop on Cassava processing and Marketing: Experiences from Ghana.

RTIMP. (2009). Cassava production guide. A Resource and Reference Manual, Kumasi, Ghana.

Sagoe, R.. (2006). Climate change and root crop porducton in Ghana. A report prepared for Environmental protection Agency (EPA), Accra, Ghana. Published by Crop Research Institute, Ghana.

Salami, B. T. and Sangoyomi, T. E. (2013). Soil Fertility Status of Cassava Fields in South Western Nigeria. American Journal of Experimental Agriculture3(1), 152-164

Sanni, L., B.Alenkhe, R.Edosio, M. Patinoand A. Dixon, A.G.O. (2007). Technology transfer in developing countries; capitalizing on equipment development. *Journal of Food, Agriculture and Environment* 5(2):88-91.

Sanni, L.O., Onadipe, O.O.,Iiona, P., Mussagy, M.D., Abass, A. and Dixon, A.G.O. (2009). Successes and challenges of cassava enterprise in West Africa: A case study of Nigeria, Benin and Sierra Leone. International Institute of Tropical Agriculture, Ibadan, Nigeria. Pp 9-11.

Schoch, T.J., (1964). Swelling Power and Solubility of Granular Starches. In: *Methods in Carbohydrate Chemistry*, Whistler, R.L., R.J. Smith and J.N. BeMiller (Eds.). Vol. 4. Academic Press, New York, USA., pp 106-108.

Sekle, C. (2011). Association of Women In Agricultural Development in Dokrochiwa, *personal communication*

Selvaraj, T . And Chellappa, P. (2006) . Arbuscular mycorrhizae: a diverse personality. Journal of Central European Agriculture 7 (2), 349-358

Setyawaty, R., Katayama-Hirayama K., Kaneko H. and Hirayam, K. (2011). Current tapioca starch wastewater (TSW) management in Indonesia. World Appl Sci. J 14: 658-665.

SKCD. (2013). Suhum Kraboa Coaltar District 2012 profile. Ministry of Local Government, Accra, Ghana.

SKCD. (2014). Suhum Kraboa Coaltar District 2013 profile. Ministry of Local Government, Accra, Ghana Ghana.

Subrahmanyam, S.N. and R.C. Hoseney, (1995). Shear thinning properties of sorghum starch. Cereal Chemistry., 72: 7-10.

Sumanjeet S. (2009). Global Food Crisis: Magnitude, Causes and Policy Measures. International Journal of Social Economics 36 (1/2), 23 – 36.

Tweneboah, C. K. (2000). Modern Agriculture in the Tropics with special reference to Ghana Food Crops. Co-Wood Publishers.

Valdez-Niebla, J.A., O. Paredes-Lopez, J.M. Vargas-Lopez and D. Hernandez-Lopez, (1993). Moisture sorption isotherms and other physicochemical properties of nixtamilized amaranth flour. *Food Chemistry*, 46: 19-23.

Van Vark, C. (2013). Cassava can become Africa's new cash crop. http://www.theguardian.com/global-development-professionals-network/2013/mar/28/cassava-food-security-sub-saharan-africa

Whiffen, L. (2007). Arbuscular mycorrhizal fungi and carbon sequestration in soil PhD thesis, School of Biological Sciences, The University of Sydney.

APPENDIX I

QUESTIONNAIRE FOR PROCESSORS

1. Name : Location: Zone:

2. Sex: Male=[1], Female=[2]

3. Educational Background and experience

- Primary=[1], JHS=[2], Middle School=[3], SSS=[4], Tertiary=[5], Others(specify)=[6]…………..........

- Number of years in processing cassava into commercial products. ………years.

4. Select the cassava varieties you frequently process. (*Choose as many as it applies*)

Afisiafi= [1], Bankyehemaa=[2], Esambankye=[3], Tuaka=[4], Agege=[5], Ankra=[6], Other(specify)=[7]……………………………………….

Give reasons for your choice in question 4:

………………………………………………………………………

5. Where do you normally get fresh cassava from for processing? Local Farmers in the district=[1], Imported from other countries/other districts=[2]

6. Select your major processed products. (*Choose as many as it applies*).

[ ] Fufu, [ ] agbelima, [ ] gari, [ ] starch, [ ] dry chips, [ ] animal feeds, [ ] *konkonte* (flour),

[ ] others, *please specify*:……………………………………………

7. Do you explore other uses of cassava? [ ] Yes [ ] No

1. If yes, mention them:

………………………………………………………………………………..

2. If no, give reasons:

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

8. Do you add value to your products? [ ] Yes [ ] No

1. If yes, mention the final

products:……………………………………………………………………

2. If no, give reasons:

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

9. Do you grade or sort your products ? Yes=[1], No=[2]

10. If yes to 9, give reasons for grading products:

………………………………………………………………………………..

11. Tick the appropriate column in the table below:

products	Shelf-life	Packaging types			
		In polythene	In bowls	In sacks	canned
Agbelima					
Gari					
Fufu					
Dry chips					
Flour (*konkonte*)					
Others,					

specify:……………..					

APPENDIX II

QUESTIONNAIRE FOR CONSUMERS

Thick where appropriate

1. Name : Location: Zone:

PRODUCT QUALITY AND ITS UTILIZATION

Which of the commercially processed products do you eat/use most? [ ] Fufu, [ ] agbelima, [ ] gari, [ ] starch, [ ] dry chips, [ ] animal feeds, [ ] *konkonte* (flour), [ ] others, *please specify*: ……………………….

2. In which form is the product sold to you? [1]=Packaged [2]=Not packaged

3. Are you satisfied with the form the products are sold to you? Yes=[ ] No=[ ]

If no, explain your answer:

…………………………………………………………………………………

4. What quality components of the products do you look out for? ....

………
……………………….

5. Do you normally buy fresh cassava for your personal processing? Yes=[ ] No=[ ]

6. If yes, choose your personal processed products? [ ] Fufu, [ ] agbelima, [ ] gari, [ ] starch, [ ] Dry chips, [ ] Animal feeds, [ ] *Konkonte* (flour), [ ] Others, *please specify*: ………………

7. Consumer preference table for the processed products of the following cassava varieties:

Please, enter the figures ***(0, 1, 2 or 3)*** *appropriately as follows:* ***0****- low (<25%);* ***1****-good (25-50%);* ***2****- very good (50-75%);* ***3****- excellent (>75%)*

	Processed products								
	Fufu	*Banku*	*Gari*	*Konkonte*	*Tapioca*	*Cassava ampesi*	*Kaklo*	*Yakayake*	*Others, speci ………………*
plains									
hemaa									
……..									

APPENDIX III

Variance, degree of freedom and normal distribution of cassava properties

Cassava variety	Variable	Variance	Degree of freedom	p-value for normal distribution
Ankrah				
	pH (supernatant)	0.0314	5	0.0001
	% Dry Matter	7.64	5	0.0503
	% solubility	2.067	5	0.0126
	Water Absorption	0.0167	5	0.0080
Afisiafi				
	pH (supernatant)	0.016	5	0.0023
	% Dry Matter	4.24	5	0.0400
	% solubility	1.63	5	0.0013
	Water Absorption	0.058	5	0.0058
Tuaka				
	pH (supernatant)	0.033	5	0.0063
	% Dry Matter	7.03	5	0.0405
	% solubility	2.044	5	0.0106
	Water Absorption	0.0175	5	0.0092
Duafra				
	pH (supernatant)	0.0444	5	0.0103
	% Dry Matter	4.74	5	0.0461
	% solubility	2.008	5	0.0103
	Water Absorption	0.0473	5	0.0477

APPENDIX IV

SOLUBILITY ANOVA

Completely Randomized AOV for solubility

Source	DF	SS	MS	F	P
Varieties	3	18.4185	6.13949	68.22	0.0000
Error	8	0.7200	0.09000		
Total	11	19.1385			
Grand mean = 2.6580 CV = 11.29					

Homogeneity of Variances F P
Levene's Test 0.00 1.0000
O'Brien's Test 0.00 1.0000
Brown and Forsythe Test 0.00 1.0000

Welch's Test for Mean Differences
Source DF F P
Varieties 3.0 52.47 0.0007
Error 4.4

Component of variance for between groups 2.01650
Effective cell size 3.0

Varieties	**Mean**
Afisiafi	1.5700
Ankrah	2.3500
Duafra	4.7500
Tuaka	1.9620

Observations per Mean 3
Standard Error of a Mean 0.1732
Std Error (Diff of 2 Means) 0.2449

Completely Randomized AOV for waterabsorption

Source	**DF**	**SS**	**MS**	**F**	**P**
Varieties	3	0.15000	0.05000	5.00	0.0306
Error	8	0.08000	0.01000		
Total	11	0.23000			

Grand Mean 1.5500 CV 6.45

Homogeneity of Variances F P
Levene's Test 0.00 1.0000

O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
Varieties	3.0	3.85	0.1019
Error	4.4		

Component of variance for between groups 0.01333
Effective cell size 3.0

Varieties	**Mean**
Afisiafi	1.7000
Ankrah	1.6000
Duafra	1.4000
Tuaka	1.5000

Observations per Mean 3
Standard Error of a Mean 0.0577
Std Error (Diff of 2 Means) 0.0816

APPENDIX V

SOLUBILITY PAIRWISE

LSD All-Pairwise Comparisons Test of solubility by Varieties

Varieties	**Mean**	**Homogeneous Groups**
Duafra	4.7500	A
Ankrah	2.3500	B
Tuaka	1.9620	BC
Afisiafi	1.5700	C

Alpha 0.05 Standard Error for Comparison 0.2449
Critical T Value 2.306 Critical Value for Comparison 0.5649
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

APPENDIX VI

ABSORPTION PAIRWISE
LSD All-Pairwise Comparisons Test of waterabsorption by Varieties

Varieties	**Mean**	**Homogeneous Groups**
Afisiafi	1.7000	A
Ankrah	1.6000	AB
Tuaka	1.5000	BC
Duafra	1.4000	C

Alpha 0.05 Standard Error for Comparison 0.0816
Critical T Value 2.306 Critical Value for Comparison 0.1883
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

APPENDIX VII

STARCH ANOVA

Completely Randomized ANOVA for DRY

Source	**DF**	**SS**	**MS**	**F**	**P**
VARIETIES	3	69.643	23.2144	5.83	0.0207
Error	8	31.873	3.9842		
Total	11	101.517			

Grand Mean 35.117 CV 5.68

Homogeneity of Variances	**F**	**P**
Levene's Test	2.53	0.1307
O'Brien's Test	1.12	0.3952
Brown and Forsythe Test	1.55	0.2745

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
VARIETIES	3.0	15.72	0.0129
Error	3.8		

Component of variance for between groups 6.41009
Effective cell size 3.0

VARIETIES	**Mean**
Afisiafi	32.600
Ankrah	33.200
Duafra	38.633
Tuaka	36.033

Observations per Mean 3
Standard Error of a Mean 1.1524
Std Error (Diff of 2 Means) 1.6298

APPENDIX VIII

Completely Randomized ANOVA for MOISTURE

Source	**DF**	**SS**	**MS**	**F**	**P**
VARIETIES	3	69.643	23.2144	5.83	0.0207
Error	8	31.873	3.9842		
Total	11	101.517			

Grand Mean 64.883 CV 3.08

Homogeneity of Variances	F	P
Levene's Test	2.53	0.1307
O'Brien's Test	1.12	0.3952
Brown and Forsythe Test	1.55	0.2745

Welch's Test for Mean Differences

Source	DF	F	P
VARIETIES	3.0	15.72	0.0129
Error	3.8		

Component of variance for between groups 6.41009
Effective cell size 3.0

VARIETIES	Mean
Afisiafi	67.400
Ankrah	66.800
Duafra	61.367
Tuaka	63.967

Observations per Mean 3
Standard Error of a Mean 1.1524
Std Error (Diff of 2 Means) 1.6298

Appendix IIX

Completely Randomized ANOVA for STARCH

Source	DF	SS	MS	F	P
VARIETIES	3	201.000	67.0000	67.00	0.0000
Error	8	8.000	1.0000		
Total	11	209.000			

Grand Mean 31.500 CV 3.17

Homogeneity of Variances	F	P
Levene's Test	0.00	1.0000
O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences

Source	DF	F	P
VARIETIES	3.0	51.54	0.0007
Error	4.4		

Component of variance for between groups 22.0000
Effective cell size 3.0

VARIETIES	Mean
Afisiafi	28.000
Ankrah	32.000
Duafra	38.000

Tuaka 28.000
Observations per Mean 3
Standard Error of a Mean 0.5774
Std Error (Diff of 2 Means) 0.8165

APPENDIX IX

STARCH PAIRWISE
LSD All-Pairwise Comparisons Test of DRY by VARIETIES

VARIETIES	Mean	Homogeneous Groups
Duafra	38.633	A
Tuaka	36.033	AB
Ankrah	33.200	B
Afisiafi	32.600	B

Alpha 0.05 Standard Error for Comparison 1.6298
Critical T Value 2.306 Critical Value for Comparison 3.7582
There are 2 groups (A and B) in which the means
are not significantly different from one another.

APPENDIX X

LSD All-Pairwise Comparisons Test of MOISTURE by VARIETIES

VARIETIES	Mean	Homogeneous Groups
Afisiafi	67.400	A
Ankrah	66.800	A
Tuaka	63.967	AB
Duafra	61.367	B

Alpha 0.05 Standard Error for Comparison 1.6298
Critical T Value 2.306 Critical Value for Comparison 3.7582
There are 2 groups (A and B) in which the means
are not significantly different from one another.

APPENDIX XI

LSD All-Pairwise Comparisons Test of STARCH by VARIETIES

VARIETIES	Mean	Homogeneous Groups
Duafra	38.000	A
Ankrah	32.000	B
Afisiafi	28.000	C
Tuaka	28.000	C

Alpha 0.05 Standard Error for Comparison 0.8165
Critical T Value 2.306 Critical Value for Comparison 1.8828
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

Appendix XII: A typical composition of the root

Moisture	70%
Starch	24%
Fibre	2%
Protein	1%
Other	3%

Starch content may be as high as 32%.

Technical Memorandum on Cassava Starch
International Starch Institute A/S, Agro Food Park 13, DK-8200 Aarhus N, Denmark