KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

CHARACTERIZATION OF STARCH FROM SOME NEW CASSAVA ACCESSIONS AT DIFFERENT MATURITY

BY

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AUGUST, 2017

CHARACTERIZATION OF STARCH FROM SOME NEW CASSAVA ACCESSIONS AT DIFFERENT MATURITY

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES,

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

(KNUST), KUMASI,

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD

OF

MSc. FOOD SCIENCE AND TECHNOLOGY

BY

GIFTY WILLIAMS

AUGUST, 2017

DECLARATION

I hereby declare that this submission is my work towards the Master of Science in Food Science and Technology and that, to the best of my knowledge, it contains no material previously published by another person nor any material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Cassava is a crop which has been used widely in the production of many products. This has activated interest in cassava-based products. It has been known as one most important sources of starch on a global scale. The aim of this research was to investigate the characteristics of starch from new cassava accessions at different maturity. Three cassava varieties (*Agra, ampong and bankyehemma*) were harvested at four different months (from April - July) after planting. Starch was extracted using the conventional method of starch extraction and the yield calculated. The amylose content was determined by means of spectrophotometry whereas pasting properties of the starches from the varieties were analyzed using Rapid Visco Analyzer. *Bankyehemma, Agra* and *ampong* had their highest starch yield in the 10th month after planting with *bankyehemma* the highest yield of 25.67±0.58 % and *Agra* having the lowest of 23.67±0.58 %. There were no significant differences in the peak viscosity, final viscosity, peak time and pasting temperature but significant differences were recorded for setback, trough and breakdown. The results showed that differences in varieties affect the starch yield and pasting properties of cassava. The amylose content of the varieties differed significantly ($p=0.05$). The highest amylose content was recorded by Agra (23.16 ± 0.03%) at the 7th month and the lowest recorded for *bankyehemma* (14.53 ± 0.12%) in that same month. Based on these results, bankyehemma can be selected and used for starch in the food industries

ACKNOWLEDGEMENT

I am very grateful to the Almighty God for granting me wisdom, favour, strength and grace to able to complete this work successfully. Ebenezer, this is how far the lord has brought me.

I am very grateful to my supervisor, Dr. Jacob Agbenorhevi for his guidance, patience, time and immerse support throughout this work.

Many thanks also to Prof. Emmanuel Bobobee of the Department of Agricultural Engineering for supplying me with the samples for this work. May God richly bless you.

I am also grateful to Mr. Michael Boateng (PhD. Student, Food Science Department) for his contribution toward this work and his time.

Special thanks to the laboratory technicians at the Department of Food Science and Technology, KNUST and all who has contributed in one way or the other for the completion of this work.

I would also like to express to my heartfelt gratitude to my sister Evelyn OsamPinanako for her financial support and prayers and also to Rev. Francis W. Aubyn for his prayers. Many thanks to all my siblings for their love and encouragement.

Finally, I would like to express my appreciation to Mr. Samuel Koomson for his great support and contribution from the start to finish. I am very grateful.

DEDICATION

I dedicate this work to the glory of God and to all my nephews and nieces.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Cassava is a perennial plant normally grown throughout the year. It is one of the most important roots crops in the world, which provides energy to consumers as it stores a lot of carbohydrates in its roots and has become a preferred root crop because of its low labor input, capital and time required in cultivation (Topouzis, 2003). As a perennial crop, storage roots can be harvested from 6-24 months after planting based on the variety and growing conditions (El Sharkway, 1993). Its high moisture content has made cassava root highly perishable and cannot be stored in the fresh state after harvest for more than a few days (Oyewole and Odunfa, 1990). It must, therefore, be converted into more stable forms (such as starch, tapioca, chips, gari, etc.) in order to increase its shelf-life (Njoku and Banigo, 2006). Cassava is mainly produced for household food consumption. Aside from its being a necessary food commodity, it has been recognized as one useful feed for livestock and poultry. It has been used in many industries in the production of products such as ethanol, syrups and biodegradable plastics (Pranamuda *et* al., 1996; Garcia & Dale, 1999). Cassava is classified as second to maize in terms of starch source worldwide and the frequently sold one (Stapleton, 2012). It has become an area of interest as a root crop for a period of time not only because of its insusceptibility to abiotic stresses (Chavez *et al*., 2005; Baguma, 2004) but also it has high productiveness with great amount of starch yield (of either 30% of fresh roots or 80% of dry matter) and pureness (Ceballos *et al.,* 2006; Benesi, 2005). The root is also recognized as important sources of starch for commercial purposes in the tropical and also subtropical countries (Moorthy, 2004).

Starch is the main constituent of cassava tubers (Ceballos *et al*., 2006) and hence plays an important role in the use of cassava as a food and as a crop for industrial purposes. It is considered as one source of starting material for production of starch in industries as it contains a high amount of starch and has many advantages for starch production due to certain properties like a high level of purity, excellent thickening characteristics, and desirable textural characteristics among others. It is a cheap source of raw material for the starch industries.

Starch is one of the fastest growing businesses worldwide which has found its application in several industries. It is a major ingredient in the foods and other nonfood industries. It can be extracted from crops like rice, potatoes, taro, wheat, yam, maize etc. and be utilized as components in various products like adhesives, food, pharmaceuticals, textiles paper and building materials and others. It is being used in textiles for sizing and dyeing to increase and enhance brightness and the weight of the cloth. In pharmaceuticals, it serves as a filler material and bonding agent for manufacturing tablets and used as thickeners, stabilizers, and additives for food processing to enhance texture and the sensory properties of the food product. Starch has various properties which make it suitable for industrial application. Some of the most important functional properties of starch that makes its suitable for its applications in food are shape, granular size, gel transparency and opacity, gelatinization and retro degradation, water absorption, solubility, syneresis, paste viscosity and gelling (Hernández-Medina *et al.,* 2008). Starch functionality is based on the average molecular weight of amylose and amylopectin, and their molecular organization inside the granule. (Allem 2002; Marti et al., 2011b; 2011c: Montagnac *et al,* 2009). Viscosity, gelatinization profile and ability to absorb water and swell are properties of starch that have been shown to depend on the composition and arrangement of the amylose and amylopectin (Lu *et al.,* 2008) the two main polysaccharides components in starch. The variation in the two components of starch is based on the botanical source, the cultivars of species and the maturation period of the same plant (Tester *et al*., 2004). Tester and Morrison (1990), stated that swelling of starch is a property of amylopectin, whiles amylose restrict it (Park *et al*., 2007; Patindol *et al*., 2007). Based on this, the difference in swelling and pasting properties in starches is mainly attributed to variation in distribution of amylopectin chain length. Paste viscosity is an important property of materials containing starch. The behavior during heating displayed on viscosity curves allows the characteristics of the paste formed by structural modifications of starch molecules and retro gradation during cooling and storage to be evaluated. Retro gradation of includes short period retro gradation mainly by amylose and long period retro gradation by amylopectin (ZHOU; LIM, 2012).

Many studies have been done on cassava and cassava products. Most of these studies focused on the effect of fertilizer applications and rainfall patterns on different varieties of the crop to estimate their starch yield. Many studies reported that starch characteristics generally alter with plant developmental stage. Polthanee *et al*., (2014) researched on the growth, starch content and yield and economic returns given by some cassava cultivars grown after rice and reported that starch content was not significantly affected by cultivars. Sriroth *et al*., (1999) reported that the age of the root and environmental conditions at harvest influences granule structure and hydration properties and the starch isolated from cassava roots, harvested at different maturities are characterized by special starch granule structure and functions.

Currently, research on cassava is on improving the quality and incorporating it into other flour to make composite flour and weaning foods (Annor Frimpong *et al.,* 1996, Bokanga 1998). It is therefore important to determine the various factors that will significantly influence the amount of starch obtained from cassava. It is in this view that this study seeks to determine some characteristics of starch from cassava as influenced by different maturity stages.

1.1 Problem Statement

As the demand for starch is on the rise due to the increasing establishment of starch utilizing industries, there is a need to find different sources of starch to meet this demand. Starch is a major component of cassava constituting about 80% and has gained importance in the starch industry because its simple isolation processes. Cassava is a relatively cheap source of raw material that can surpass or equal properties given by starches from other cereals and roots tubers. Review of literature shows different studies on various cassava varieties and products of cassava in Ghana and many parts of Africa. Nonetheless, as new and improved cultivars are being developed, it has become important to extract starch from these new cultivars for further studies so as to know their functional and physiochemical properties. These studies are needed to encourage starch industrialists to engage in large scale cassava starch production. The starch yield from cassava is dependent but not limited to the variety, maturity, cultivation practices and extraction methods. When cassava roots are selected for starch extraction, the age of the root and variety are critical factors. Previous studies have reported that maturity is one of the factors that influence starch yield. This research takes into consideration starch yield and pasting properties as affected by different maturity stages.

1.2 Justification

The increase in development of new and improved varieties of cassava will lead to increased source of raw material for the starch industry which is readily available. Different research works have been done on various factors that affect starch yield from cassava (varieties) and cassava products, however, limited work has been done on cassava at different maturity stage and their effect on the starch yield and pasting properties. The research seeks to characterize starch from new cassava accessions at different maturity to determine the effect of harvesting times on the starch yield and pasting properties.

1.3 Objectives

To characterize starch from some new cassava accessions at different maturity.

1.4 Specific Objectives

- To evaluate the effects of maturity stages on yield and pasting properties of cassava starch.
- To determine the amylose and amylopectin content of cassava starch.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 History and Botany of cassava

In most of the farming communities in Ghana, cassava (scientific name: *Manihot Esculanta*) is one of the popularly produced crops used as food. Cassava primarily provides starch as a nutritional formula and meets the occupational vacuum in the lives of most rural folks. According to the Ministry of Food and Agriculture (MoFA)
22% of the Agricultural Gross Domestic Product is provided by cassava (MoFA, 2005).

Originating from Brazil, Nweke (1997) disclosed that cassava was spread out to the tropical areas of Africa by Portuguese farmers. In the 16th and 17th centuries, Brazilian merchants of the Congo River and Southern America had gotten and were growing cassava on large scales. In Ghana, formally Gold Coast, cassava was introduced by the Portuguese, who cultivated the crop around their forts and castles to feed themselves and their slaves. In the middles of the 18th century, majority of the farmers along the coastal plains of Ghana had adopted and grew cassava for both commercial and domestic purposes (Bentil, 2011).

Gaining firm grounds in the coastal belt of the country, cassava did not easily and speedily diffuse to the forest zones of Ghana (Ofori, 2005). Cassava‟s spread took a steady form in the 1930s as it got to the Ashanti‟s, extended through the Brong Ahafo Region and later to the northern parts of the country. It must be stipulated that cassava actually became a popular crop during the early days of 1980‟s where the el-Niño generated famine stroked the country. During this period, virtually all the preferred food crops like plantain, cocoyam, sorghum and millet in the northern and middle parts of Ghana failed and cassava came to their rescue (Korang-Amoakoh, Cudjoe & Adams, 1987 cited in Ofori, 2005). Beginning from the 1980s, cassava has become an accepted eating crop used in preparing several types of dishes as, *gari, fufu* and konkonte which are popular foods eaten throughout Ghana which was not so some years ago when they were only eaten in the coastal regions.

2.2 Importance of Cassava in Ghana

According to Alderman and Higgens (1992), the total cultivation, crop area and great addition to Agricultural Domestic Product (AGDP) are the basis for measuring the benefits of cassava. Within a ten year period between 1986 and 1996, the growth of cassava increased that the average planted area of 386 000 ha in 1986 shot to 590, 000 ha in 1996. Such increase is evident in the significant rise in the production of cassava ranging from 2.9 million tonnes to 7.11 million tonnes. The crop has become the largest agricultural product cultivated in Ghana, representing 22 % of AGDP compared to 5 % for maize, 2 % for rice, sorghum and millet, 14 percent for cocoa, 11 percent for forestry, 7 percent for fisheries and 5 percent for livestock (Al-Hassan, 1989; Dapaah, 1996)

2.2.1 Ecological Importance

It is revealed by several researchers of Cassava that it serves as the major food security in the world. Apart from this major role, arbuscular mychorrizal fungi (*Glomus spp.*) are the commonest organisms in symbiotic association with cassava roots. Biologically, 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 & Cavagnaro, 2012). It has also been found that mychorriza encourages uptake of Ca, K 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 hinders population of feeding nematodes of the root of the plant (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 & 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 & 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 & Chellappa, 2006). The exudates may signal for an increased microbial population in the root zone.

2.2.2 Socio-Economic Importance of Cassava

According to FAO (1998) cassava is literally called agbeli in Ewe language which means "by it life exists" by many coastal West Africans. Cassava plays an important role in Ghana by accounting for 22% of the national GDP (Sagoe, 2006). 60% of Ghanaian population takes Cassava and its products serves as daily caloric intake making it form almost every household (Sanni, *et al,* 2009). In most part of Ghana, cassava serves as source of livelihood and food security (MoFA, 2009).

2.2.3 Nutritional Value of Cassava

Duffour (1995) asserts that Cassava root is rich in carbohydrate accounting for (30–35 %), and less in protein (1–2%), (< 1%) fat, and other minerals and vitamins. It is established that starchy foods such as roots and tubers, cereals, and other leguminous crops have higher nutritional content compared to cassava; it contains carbohydrate approximately 64 to 72% in the form of amylose and amylopectin. About 0.5% of lipid is contained in cassava and essential amino acids mainly lysine, methionine and tryptophan are very low (Smith, 1988). Cassava contains significant amounts of calcium, phosphorous and vitamin that is (50 mg/100g), (40 mg/ 100g), (25 mg/100g) respectively. The starch produced from cassava is normally digestible and produces 23% protein, vitamins and minerals from the intake of cassava leaves (Duffour, 1995).

2.3 Composition of Cassava

The composition of cassava is not constant. There is diversity in the composition of cassava, in relation to the geographical area (characterized by vegetation and climate) where it is planted, the specific tissues (leaves and roots), the variety and maturity of the plant and environmental parameters (Garcia and Dale, 1999). The composition of cassava by roots and leaves are as reviewed in the following section.

2.3.1. Composition by Roots

Cassava roots are used for a lot of purposes ranging from animal feed to pharmaceutical significance. The production of cassava roots has grown steadily since the 1960s representing more than 40% increase in production, the root production of cassava rose from 161million tonnes in 1997 to 224 million tonnes in 2007 (Morgan and Choct, 2016). Stupak (2006) establishes that cassava is wholly made up of carbohydrate with approximately between 1% and 3% crude protein. Many scholars have measured and presented the Metabolizable Energy (ME) levels of the root of cassava. These levels are presented as 3,000 to 3,200 kcal/kg (Buitrago *et al*., 2002), 3,200 kcal/kg (Egena, 2006), 3145 kcal/kg (Khajarern and Khajarern, 2007) and 3,279 kcal/kg (Olugbemi *et al.,* 2010).

The cassava root is further processed into chips and pellets and mash forms. These root chips and pellets are widely produced in the northern part of Africa for poultry feed (Chayunarong *et al.,* 2009). The roots are fragmented into chips that are dried under the

sun to completely minimize the moisture level to about 14%. (Oguntimein, 1988). Exporting cassava products follow a standard procedure. Balagopalan identifies the specifications for the export of cassava chips at a maximum of 5% fibre,
3% soil contaminants, 14% moisture and a minimum of 65% starch (Balagopalan, 2002). Cassava chips, whether exported or domestically used, have different sizes, shapes and quality. The quality of cassava chips relies on the rate of drying and level of contamination during processing. The bulky cassava chips are reduced to pellets for animal feed to improve performance and ease in transportation. During processing of chips and roots, cassava meal is the residue that drops as a result of the processing.
According to Chauynarong *et al* (2009), cassava meals are frequently used in Africa. In Europe however, other cassava products dominate the market due to their lower starch content and presence of soil contaminants (Chauynarong *et al.,* 2009).

Local processing of cassava involves peeling to get rid of the skin and leathery parenchymatous covering which makes up approximately 15% to 20% of the tuber (Obadina *et al.,* 2006; Onyimonyi and Ugwu, 2007). Obadina et al (2006) suggests that there is higher potential for this waste to be exploited by biotechnological systems. Cassava peel meal is low in both energy and protein and contains higher levels of cyanogenic glucosides than root meal (Ngiki *et al.,* 2014). According to Tewe (1991), the approximate amounts of cyanide in bitter tasting cassava peel and pulp are respectively 650 and 310 mg/kg. Similarly, he found 200 and 38 mg/kg for the peel and pulp respectively in sweeter varieties.

Cassava peel meal is likely to be protein deficient, as the protein content measure approximately 46 to 55 g/kg, quite less than that of other cereals. This makes it a relatively bad alternative as replacement for other cereals. The root products of cassava lack carotene and carotenoids, necessitating the addition of supplements to diets containing these products to maintain normal egg yolk and broiler skin pigmentation (Khajarern & Khajarern, 2007). In the same way, diets containing leaf meals of cassava is likely to generate such problem. Cassava pulp is the solid, moist end product of cassava starch production, representing about 10% to 15% of the root (Thongkratok et al., 2010). There is 60% to 70% moisture content of cassava pulp and a 50% carbohydrate content when it is dry. The protein content of dried cassava is low, approximately 2%. Dry cassava pulp is also deficient in carotene but has a lot of fibre in it (thus in soluble fibre forms) making it unsuitable for poultry diets

2.3.2. Composition by Leaves

Approximately 10 tonnes of dry cassava foliage is produced per hectare. Cassava leaves are highly nutritious. They have high protein, ranging from 16.6% to 39.9% (Khieu *et al.,* 2005), and mineral levels, as well as being a valuable source of vitamin C and B(1and2) and carotenes (Adewusi & Bradbury, 1993). Additionally, concentrations of amino acid in cassava leaves is almost the same as that of alfalfa (Ravindran, 1991) and the ME ranges from approximately 1590 kcal/kg (Khajarern & Khajarern, 2007) to 1,800 kcal/kg (Ravindran, 1991). Dry cassava leaves can therefore be ground into meal and used as fed for poultry which serves as a source of protein and carotene (Khajarern & Khajarern, 1992). Cassava leaves can be harvested in a period of 4 to 5 months after planting, without having any adverse effect on the root. As the leaf ages, crude protein and amino acid levels decrease, but crude fibre, hemicellulose and cellulose levels increase (Ravindran 1992). Cassava leaves have a significant level of the anti-nutrients hydrocyanic acid (HCN), low digestible energy and high tannin and phytin content which limits their use in poultry feed (Ravindran *et al.,* 1986).

Table 2.1: Comparison of Chemical Composition of Cassava with those of other Materials

Material	Moisture	Protein %	Ash %	Fibre %	Fat %	Starch %
Cassava	65	0.8-1.0	0.3-0.5	0.8	0.2-0.5	32
Cassava flour	17	2.1	1.0	0.7	0.1	20
Potato	15	-	0.3	0.4	0.3	82
Husked Rice	15	8.0	1.5	0.7-1.0	2.5	73
Wheat	9-18	8-15	1.5-2.0	2.0-2.5	1.5-2.0	65
Wheat Flour	14	8-13	0.3-0.6	0.1	0.8-1.5	68

Source: Darkwa & Jetuah (CSIR, 2003)

Table 2.1 gives the chemical composition of wheat flour, cassava flour and other starch containing materials. It shows that the chemical composition of wheat flour is not very different from that of cassava flour. The major difference is the amounts of protein, which is about 10% in wheat flour and only 0.6% in cassava flour. This is significant for Adams *et al* (1969) which stated that wheat flour is a better material as an extender than the tuber starch because of the presences of protein in the wheat

flour.

The other significant properties, which show differences between cassava flour and wheat flour, are the % fat and % starch. Percentage fat is lower in cassava while % starch is higher in cassava. Thus in order to use cassava flour as extender its physical and chemical properties needs to be studied.

However, the physical and chemical properties of cassava, like most natural materials, would be influenced by genetic and site factors. Thus in this activity, various cassava varieties were analyzed for their physical and chemical composition. It is also known that the method used in processing agricultural material do have effect on the composition of the final product. Processing procedures like: drying, mechanical treatment before drying, sieving and also the storage time, do have effect on the composition.

Table 2.2 below displays figures representing harvested quantities of cassava. MOFA/SRID (2012) in addition to an estimation of an additional 30% remains in the ground which are not harvested (Onumah *et al.,* 2008) because of little demand, lack of buyers, and due to weak marketing networking.

One of the most important staple foods in Ghana which thrives well on marginal lands is cassava. Production of the crop represents approximately 50% of all production of roots and tubers production in the country. Cassava is grown mainly by small-scale farmers with small landholdings. On this production rate, harvesting, and handling after harvest are carried out with minimum technical and chemical inputs.

Cassava is planted in almost all regions of Ghana but is mainly abundant in Eastern Central and Brong Ahafo, Volta, and Ashanti regions as indicated in Table 1. A statical observation by MOFA indicated that cultivation of cassava roots has risen to almost

40% from 2007 to 2011. This is as a result of large increase in average yield per hectare of 26% within that period from 12.76 to 16.17 tonnes per every hectare (Kleih *et al,* (2013). The land usage for production increased to 11% in that time.

Table 2.2: Cassava Production Estimates in Ghana (2007-2011)

Region	Estimation of cassava production in Ghana from 2007-2011 in Metric Tonnes (MT)				
	2007	**2008**	**2009**	**2010**	**2011**
Western	690,396	707,894	744,950	687,350	556,700
Central	1,861,160	1,992,384	2,036,500	1,914,979	1,976,946
Eastern	2,619,247	2,929,343	3,062,770	3,618,825	3,858,149
Greater Accra	56,576	64,279	67,530	68,170	71,863
Volta	1,048,075	1,357,227	1,558,480	1,529,022	1,660,007
Ashanti	1,160,603	1,205,218	1,255,190	1,842,666	1,900,444
Brong Ahafo	2,426,982	2,489,550	2,606,970	2,728,351	2,883,353
Northern	354,890	605,201	931,240	1,114,723	1,333,406
Upper West	-	-	-	-	-
Upper East	-	-	-	--	--
Total	**10,217,929**	**11,351,095**	**12,230,630**	**13,504,086**	**14,240,867**

Source: MOFA/SRID 2012 cited in Kleih et al, (2013)

2.4 Types of Cassava

Varieties of cassava also referred to as *cultivars* are grouped by their morphological traits taste, average yield, cyanide content, disease performance and pubescence (MIC, 2007; Gbadegesin *et al.,* 2013).Over 5,000 cassava varieties are recognized worldwide (Best, 1993; Bokanga, 1994; Gade, 2003; IFAD/FAO, 2005)

Cassava has been classified into two major groups that is: sweet and bitter (ChiwonaKarltun *et al.,* 2004; Mkumbira *et al*., 2003; MIC, 2007). The amount of cyanogenic glycoside present affects the taste (McKey & Beckerman, 1993; Chiwona-Karltun *et al.,* 2004). Cyanogenic glycosides is between the range of 10 to 500 mg cyanide equivalent/kg dry matter in the roots (Arguedas, 1982; Siritunga & Sayre, 2003) whereas its leaves are made up of between 53 to 1,300 mg cyanide equivalents/kg of dry weight (Siritunga and Sayre, 2003; Wobeto *et al.,* 2007). Bitter cultivars carry over 100 mg/kg fresh weight of hydrogen cyanide (Dufour, 1988; McKey *et al.,* 2010).

These bitter varieties constitute more than 90% of cultivated cassava and they have great yield, are resistant to pests and diseases and can be stored in the soil for more than 12 months (Chiwona-Karltun *et al,* 1998; MIC/FAO/EC, 2004; Mader, 2005). Bitter cassava requires processing in other to remove cyanogenic glycosides before consumption (Zvauya et al., 2002; Cardoso et al., 2005; Bradbury, 2006; Cumbana et al., 2007). Contrary to the bitter varieties, the Sweet varieties consist of less than 100 mg/kg fresh weight of hydrogen cyanide, and are eaten fresh, or even raw at certain times (Dufour, 1988; Mowat, 1989; Cardoso *et al.,* 2005; Bradbury 2006; Cumbana *et al.,* 2007; Donovan *et al* 2011).

Table 2.3: Varieties of Cassava in Ghana

Name of Variety	Distinctness, Uniformity and Stability (DUS)	Value for Cultivation and Use (VCU)	Preferred Ecology
Afisiafi	Petiole colour: light green Mature leaf: green Branching: open branching Outer skin of the root: pale reddish brown Root spread: horizontal Cooking ability: not poundable Wider adaptation Young stem: light green Mature stem colour: greenish brown Tuber texture: rough Shape: cylindrical	Maturity period: 12 to 15 months Mean root yield: 28 -35 t/ha Total root dry matter: 32% Used for starch, gari and flour Tolerant to Cassava Mosaic Virus (CMV)	All agro-ecologies in Ghana
Abasafitaa	Relatively short in height Low branching Wide open canopy Profuse flowing Colour of mature leaf: greyish green Root tuber: long horizontal Outer skin colour: dark greyish Inner skin colour: light greyish Petiole colour: light greyish Mature stem colour: greyish Interval between the branching: short	Relatively short in height Mean root yield: 29 -35t/ha Total root dry matter: 35% Used for starch, gari and flour Tolerant to Cassava Mosaic Virus (CMV)	Forest Savannah Transition
Tek-Bankye	Leaf colour: light green Mature leaf colour: dark green Petiole colour: green and purple Stem colour: light brown Level of branching :> 3 Root tuber: cream Texture: smooth Position: horizontal Neck length: long	Maturity period :12-15 months Mean root yield: 30-40t/ha Total root dry matter: 30% Used for fufu, gari and"Ampesi" It is prone to viruses like Cassava Mosaic Virus (CMV)	Savannah forest /Forest Transition

NyeriKobga	It has a storage root surface texture which is not smooth, but has no limitations on the storage root	Fresh root yields 17-29t/ha and have high yield both 8 and 12 MAP. Roots cannot be pounded in dry seasons it can be used for Tua Zaafi, gari, flour and starch	Guinea Savannah
Eskamay	Has a storage root texture which is rough, but has no limitations on it Stem colour is greenish grey	Fresh roots yields 16-23t/ha and have high yield at both 8 and 12 MAP. Has high gari swelling ability. during the dry season poundability cannot be achieved It can be used for Tuo Zaafi, gari, flour and starch	Guinea Savannah
Fil-Ndiakong	It has root constrictions due to a smooth storage root and surface texture. Stem colour is brownish grey	Fresh roots yield 16-19 t/ha and have high yield at 8 MAP than 12 MAP, therefore is an early variety. High dry matter but small root sizes. Recommended for gari, flour and starch. Roots are not poundable in the dry season. Boiled roots have sweet taste	Guinea Savannah
Nkabom	Young Stem colour: green; Petiole: purple; Mature stem colour: silver green; Branching habit: intermediate; Tuber shape: conical (long); Outer colour: dark brown	Maturity period:12-15 months; Mean Root yield:28-32t/ha; Total Root dry matter :32%;Used for starch and fufu;	Transition in, Forest, ForestSavannah, coastal savannah

IFAD	Young stem colour: green; Petiole :purple; Mature stem colour: silver green; Branching habit: high; Tuber shape: conical (long); Outer colour: dark brown	Maturity period:12-15 months; Mean Root yield:30-35t/ha; Total Root dry matter :320%; Used for starch and fufu;	Coastal Savannah, transition in Forest, Forest-Savannah
CRI- Otuhia	Petiole colour: yellowish green, Stem colour: grey, Mean height:189cm, Root skin colour: brown	Potential yield: 35 t/ha, Dry Matter 39%, Tolerant to Cassava Mosaic Virus (CMV), Good for starch and flour production.	Forest, coastal and forest-Savannah transition
CRI- Agbelifia	Petiole colour: purple, Stem colour: greyish brown, Root skin colour: brown Growth habit: No branching,	Potential yield: 350.8t/ha 24.4% starch Good for starch and flour production.	Forest, coastal and forest-Savannah transition

Source: CSIR, 2014

2.5 Development of Cassava

2.5.1 The Future of Cassava in Africa

According to FAO and IFAD report on Cassava transformation in Africa, the future of the development of Cassava depends on individual countries centering their cassava market around the provision of an enabling environment through, adequate and improved access of farmers to input and output markets, and also development and adoption of improved cassava cultivars with the required traits and characteristics in local communities and other sustainable practices.

Table 2.4: Population and Income Growth effects on Cassava in Africa

Situations	Increased per capita income	Rise in population

Rise in per capita income		Increased incomes lead to a greater demand for diversity in the diet. Demand for carbohydrates like cassava will be on a rise as fast as that for other staples. Replacement also takes place within the starchy staples, but increased population will lead to higher demand for fresh tubers and processed products
Lower per capita income		This will increase the requirements for various cassava products.
Interventions by Government	Some limited help to producers - restrained by the extent to which consumers turn to less starchy staples	Constrained by the extent to which the market can engulf the increased production - a factor influenced by post-harvest processing costs.

Source: ***Dunstan Spencer and associates: FAO Corporate Documentary Depository***

Table 2.5: Challenges specific countries for Cassava Sector Development Table

Country	Challenges in policies	Genetic Research, Protection Plant, Agronomic Practices and TMS Diffusion	Food Preparation and Processing
Nigeria	Research and Development	Improved varieties that produces a maximum yield in 12 months or less Improved labour-saving mechanisms for cassava harvesting	Improvement in laboursaving method for toasting gari Diffuse the cassava leaves Preparation methods

Ghana	Research and development Support for increasing the use of cassava in industry	Develop cultivars that produces maximum yield in less than 12 months TMS multiplication and diffusion Develop labour-saving technology for cassava harvesting	Develop labour-saving method for toasting gari Diffuse the cassava leaves Preparation method
Uganda	Research and Development Support for increasing the use of cassava in industry	TMS multiplication and diffusion Develop labour-saving technology for cassava harvesting	Diffuse gari preparation methods Diffuse mechanized grater technology Diffuse the cassava leaves Preparation method
Cote d" voire	Eliminate subsidies on imported rice and wheat	TMS multiplication and diffusion TMS multiplication and diffusion	Develop a grater that is suitable for attieke processing Diffuse the cassava leaves preparation method
Tanzania	Proper and easy road access to urban markets		Diffuse gari preparation methods Diffuse mechanized grater technology
Congo	Improved road access to urban markets centers Road access to urban market centers Eliminate subsidies on imported rice and wheat		Diffuse the mechanized grater technology Diffuse the mechanized grater technology

Source: Nweke et al. 2001 cited in IFAD Report, 2005

2.6 Starch

2.6.1 Scientific Information on Starch

Starch is said to be a homopolysaccharide formed by the combination of glucose units and acts as the storage form of carbohydrates in plants. It is the major reservoir for carbohydrate in the roots of plant and seed endosperm where it is appears as granules. Maize is the largest starch source with other sources being wheat, cassava, potato, and rice. Starch consists basically of D-glucopyranose polymers with a α-1, 4and α-1, 6 glucosidic bonds termed as amylose and amylopectin respectively (Wurzburg, 1986). Formation of These bonds are as a result of the carbon number 1 (C1) on a DGlucopyranose molecule reacting with carbon number 4 (C4) or carbon number 6 (C6) from an adjacent D-glucopyranose molecule. The free aldehyde group on the end of the starch polymer makes starch polymers have at least one reducing end (Wurzburg, 1986). Starch polymers are made up of only α-linkages which allow some starch polymers to form helical structures compared to the β configuration of cellulose which forms the sheeted ribbon-like structures.

Fresh cassava roots contains 30-40 % dry matter of which 85percent is starch. . They are increasingly used as raw commodity for starch based products because of the rich starch in their roots. About 25 percent starch can be extracted from matured, good quality roots. 60 percent of starch can be gotten from dry cassava chips and about 10 percent dry pulp obtained per 100kg of the roots (Oyewole and Obieze 1995).

2.6.2 Rheological and Thermal Properties

Pastes from Starch are formed instantly when gelatinization is complete, and starch granules are progressively subject to breakdown by shearing since they are enlarged. The paste produced is a viscous mass made up of one progressive phase of solubilized amylose and/or amylopectin and one discontinuous phase of the starch granules left (Ambigaipalan *et al*., 2011). Functionality of starch is influenced directly by gelatinization and other properties of the paste. All of these parameters affect the stability of products, production reliability and consumer acceptance (Šubarić *et al*., 2012).

Characterization of the native starch, the influence of the physical or chemical changes of the granules, the process requirement and the biological sources of the starch are crucial factors associated with the behavior and characteristics of the starch paste. The changes undergone by starch during production is dependent on the temperature verses time and mixture ratio and the modification ratio in the course of production (Conde-Petit *et al.,* 2001).

Starch granules are not soluble in cold water because of the hydrogen bonds and crystalline nature of its molecules. Dispersion of starch in hot water below its Tg, the granules of the starch swells and increases many times in size, disintegrating the molecules and eventual leaching of amylose to produce a three-dimensional structure and increase the viscosity of the paste (Sarker *et al.,* 2013). Starch paste can contain un-swollen granules, moderately swollen granules, and aggregates of swollen starch granules, particles and molecules of retrograded and dissolved starch or precipitated (BeMiller and Whistler, 2009)

The relatively short chains found in the amylose and amylopectin gives starch suspensions its opacity as well as foods containing them. Starch opacity is not disadvantageous in products such as sources, dressings and puddings, but jellies and fruit fillings needs starch suspensions with high clarity (Eliasson, 2004). Paste clarity is normally determined by percentage transmittance of a dilute starch solution of (1% w/w) at a wavelength of 650 nm (Ulbrich *et al.,* 2015). Commodities such as potato starch have 42 to 96% transmittance and are classified as high clarity pastes, followed by starch from cassava at 51-81%. Some cereals normally indicates transmittances of 13 to 62% (Craig *et al.,* 1989; Nuwamanya *et al.,* 2013). Low clarity in common cereals is as a result of the amount of swollen starch granules traces it contains (Craig *et al.,* 1989) and complexes of amylose-lipids (Bello-Pérez and Paredes-López, 1996).

Modification in Clarity of starch suspensions during storage, decreases due to amylose and/or amylopectin molecules (Waterschoot *et al.,* 2015a)

Rheological properties describes how materials subjected to shear forces and deformation behaves, which are considered viscoelastic properties. The primary feature of rheology of starch is its viscosity. Rheological characteristics includes others like texture, shear strength transparency or clarity and the ability to retrograde. All of these parameters plays significant roles in applications of commercial starch (BeMiller and Whistler, 2009; Berski *et al.,* 2011). Rheological starch properties are studied by means of the behavior of viscosity curves, which are dependent on temperature, concentration and shear stress (Singh *et al.,* 2003).

"Pasting properties" is a terminology which describe the transformations that occur in starch when it is gelatinized in excess water analyzed by an instrument such as the Rapid Visco Analyzer (RVA) .It is a measure of the viscosity as functions of temperature and time. Paste behavior in RVA is described in three periods:

(i) a period of heating period which is controlled whiles increasing the temperature of the suspension from room temperature to 95 °C;

(ii) An isothermal period, stabilizing the suspension at the peak temperature for analysis.

(iii) A cooling period, involving decreasing the temperature to a temperature of 50 °C., shear forces acts on the suspension throughout the analysis. Suspensions shows a peak in viscosity that begins after gelatinization and increases with swelling of the granules, after which viscosity decrease because of granule breakdown and polymer realignment. A "Breakdown" is given as the difference in the viscosity peak and the minimum viscosity at the maximum temperature of the analysis. Amylose leaches from the three dimensional structure to forms a gel during the period of cooling. Gel formation increases the viscosity further, known as "cold paste viscosity". Setback is described by the difference between the paste viscosity at the end of the cooling period and the minimum viscosity at 95 °C (Saunders *et al.,* 2011; Wang & Weller, 2006)

2.6.3 Specific Uses of Starch

fresh root of cassava contains 30% to 40% of dry matter specifically of which 85% is starch. Because of the rich starch content of cassava, it is widely used as raw materials for products containing starch. About 25% starch can be isolated from mature and good quality roots. About 60% starch may be isolated from dry cassava chips and about 10% dry pulp may be extracted per 100kg of the crop (Oyewole & Obieze 1995).

Unique properties of cassava starch includes but not limited to high paste viscosity, high paste clarity, and high freeze-thaw stability, which are of many advantages to industries that uses starch in their production. (Oyewole & Obieze 1995).Cassava starches are potential replacement for wheat and maize–based starches (Rickard *et al*., 1991, Tian *et al.,* 1991).

Dziedzoave et al.,(2000) observed in a survey that Ghana uses 5000t of starch per annum which represents (40%) textiles, (27%) plywood , pharmaceuticals (20%), paper (10%), and food (3%) in each of these sectors.

Hydrostats of starch are produced by hydrolysis of starch with acid or enzyme treatment are used to induce sweetness, texture and Cohesiveness to drinks such as soft drinks, fruit juice and dairy drinks and to a wide range of foods such as soup, cake and cookies (Balagoplan et al, 1998).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Materials

New varieties of cassava named *Agra, bankyehemma* and *ampong* were harvested from Kwame Nkrumah University of Science and Technology (KNUST) school farm, Anwomaso in the Ashanti Region of Ghana. The varieties were harvested on the 7th month, through to 8, 9 and 10 for this research.

3.2 Methods

3.2.1 Extraction of Starch

The starch extraction was done at the Sensory laboratory in the Food Science and Technology Department (KNUST). The starch was extracted using the conventional method of starch extraction.

The freshly harvested cassava tubers of all the varieties were peeled and washed. The washed cassava were then grated using a metal grater. 100g of the grated cassava was measured using a mass balance (Model: ML204/01, Mettler Toledo, Switzerland) and blended with 100 ml of distilled water with a stainless-steel warring blender for 1 min for each variety.

The slurry was sieved using cheese cloth in a mesh into a container (bowl). It was then washed with extra distilled water until the cassava was fibrous. The filtrate was allowed to stand for 5 h and then decanted.

The starch material was then air dried for 2 days at room temperature. The masses of the dried starch was measured and then packed in zipper locked bags. Yield for each variety was calculated from the mass of the dried starch and the mass of the crated cassava (100g) expressed as a percentage.

3.2.2 Moisture Content

Moisture content was determined by official method. 5 g of the dried starch of each variety were measured with the aid of a mass balance (Model: ML204/01, Mettler Toledo, Switzerland) into a petri dish of known mass. The samples in the Petri dishes were placed in a forced-air oven at a temperature of 105℃ for 5 h.

The samples were removed and placed in a desiccator to cool. The cooled samples were weighed and the moisture content calculated from the difference in masses and expressed as percentage.

3.2.3 Pasting Characteristics

Rapid Viscos Analyzer Model 4500 (RVA) was used in the analysis of the pasting properties of the starch at the Food Science Laboratory in KNUST. The calculated moisture content was inputted into the RVA which gives the mass of starch and water to be measured. The masses displayed by the instrument were measured into a dried empty canister. The starch solution was mixed thoroughly and then placed into the RVA. The starch slurry was heated from 50 to 95℃.

3.2.4 Amylose and Amylopectin

Amylose was determined using iodine colorimetric method

3.2.5 Standard Amylose Curve

0.04 g of a standard amylose was measured into a 100 ml volumetric flask. 1 ml of ethanol (95%) was added to the amylose.9ml of 1N NaOH was added to the mixture.

The mixture was then heated for 10 minutes in boiling water bath and allowed to cool to 28℃. Distilled water was used to top up the solution to the 100 ml mark.

1, 2, 3, 4 and 5 ml aliquots of the prepared solution were pipetted into five different 100 ml volumetric flasks. 2 ml of iodine solution was added to each of the five flasks. Volumes (0.2, 0.4, 0.6, 0.8 and 1.0 ml) of acetic acid were added to the aliquots of volumes 1 ml, 2 ml, 3 ml, 4 ml and 5 ml respectively. The content of the flask was then topped up with distilled water to the 100-ml mark and shook to mix well. The flasks and its contents were allowed to stand for 20 min. A control sample was prepared by filling a 100-ml volumetric flask with distilled water and then adding 2 ml of iodine solution.

The absorbance of the solutions at 620 nm was measured and recorded using a spectrophotometer (SHIMADZU SPECTROPHOTOMETER UV-1800). The absorbance of the five different solutions and the control was used to plot a calibration curve.

3.2.6 Amylose Procedure for Cassava Starch

0.1g of cassava starch was measured with the aid of a mass balance (Model: ML204/01, Mettler Toledo, Switzerland) into a 50-ml conical flask. 9 ml 1N NaOH and 1 ml of ethanol (95%) were added to the cassava starch. The mixture was heated for 10 minutes in a boiling water bath and then cooled to 28℃.

The mixture was then poured into a 100-ml volumetric flask with several washings. The mixture was topped up with distilled water to the 100-ml mark and shook to mix thoroughly.

5 ml of the mixture was measured into a new 100-ml volumetric flask. Acetic acid and iodine solution of volumes 1 ml and 2 ml respectively, were added to the mixture. The mixture was then topped up with distilled water to the 100 ml mark. The mixture was shook to ensure uniform mixing and allowed to stand for 20 min. The absorbance of the mixtures were taken at 620 nm with a spectrophotometer (SHIMADZU SPECTROPHOTOMETER UV-1800). Concentration of amylose in the samples were determined using the calibration curve. The amylopectin content was calculated by subtraction the percent amylose from 100.

3.2.7 Statistical and Data Analysis

Data was analyzed statistically by Statistical Package for Social Sciences (version 19). Two-way analysis of variance was used to generate the mean and standard deviations.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Yield

Table 4.1 shows the results for a yield of starch of three different varieties of cassava at different months.

Table 4.1: Percentage Yield, Amylose and Amylopectin of Three Varieties of Cassava at Different Maturity

Maturity/Variety	Yield (%)	Amylose	Amylopectin
Month 7			
Bankyehemma	19.33 ± 0.58^{a}	14.53 ± 0.12^{a}	85.47 ± 0.12^{c}
Ampong	19.00 ± 0.00^{a}	20.51 ± 0.87^{bc}	79.49 ± 0.87^{a}
Agra	19.67 ± 0.58^{ab}	23.16 ± 0.03^{c}	76.84 ± 0.03^{a}

Month 8			
Bankyehemma	22.00 ± 1.73^{bc}	22.20 ± 0.16^{bc}	77.80 ± 0.16^{ab}
Ampong	23.33 ± 1.16^{cd}	22.24 ± 2.55^{bc}	77.76 ± 2.55^{ab}
Agra	21.67 ± 1.53^{bc}	19.80 ± 0.73^{bc}	80.20 ± 0.73^{ab}
Month 9			
Bankyehemma	25.00 ± 1.00^{d}	20.84 ± 0.71^{bc}	79.16 ± 0.71^{ab}
Ampong	24.67 ± 0.58^{cd}	19.16 ± 0.52^{abc}	80.84 ± 0.52^{abc}
Agra	23.33 ± 0.58^{cd}	21.08 ± 0.10^{bc}	78.92 ± 0.10^{ab}
Month 10			
Bankyehemma	25.67 ± 0.58^{d}	19.43 ± 0.94^{bc}	80.57 ± 0.94^{ab}
Ampong	25.00 ± 0.00^{cd}	19.62 ± 0.45^{bc}	80.38 ± 0.45^{ab}
Agra	23.67 ± 0.58^{cd}	17.52 ± 0.38^{ab}	82.48 ± 0.38^{bc}

BH = *Bankyehemma*, AM = *Ampong* and AG = *Agra. Values are* Mean ±SD. Mean values in column under the same month with different superscript letter are significantly different ($p < 0.05$).

Table 4.2: Pasting Properties of Three Varieties of Cassava at Different Maturity

Varieties	Peak Viscosity(cP)	Trough(cP)	Breakdown(cP)	Final viscosity(cP)	Setback(cP)	Peak time	Pasting temp
Month 7							
Bankyehemma	4290.5 ± 36.1^{a}	2419.0 ± 127.3^{b}	1817.5 ± 91.2^{ab}	3182.0 ± 128.7^{a}	763.0 ± 1.4^{ab}	4.07 ± 0.2^{a}	73.18 ± 0.7^{a}
Ampong	3904.5 ± 252.4^{a}	2199.0 ± 17.0^{ab}	1705.5 ± 235.5^{a}	2730.0 ± 84.9^{a}	531.0 ± 67.9^{a}	4.30 ± 0.2^{a}	78.33 ± 0.0^{a}
Agra	4245.5 ± 398.1^{a}	2006.0 ± 15.6^{ab}	2239.5 ± 413.7^{ab}	2736.0 ± 398.8^{a}	730 ± 414.4^{ab}	4.00 ± 0.2^{a}	76.80 ± 0.0^{a}
Month 8							
Bankyehemma	4541.0 ± 244.7^{a}	2098.5 ± 31.8^{ab}	2442.5 ± 276.5^{ab}	2993 ± 94.1^{a}	894.5 ± 3.5^{ab}	4.17 ± 0.1^{a}	72.7 ± 0.1^{a}
Ampong	4783.5 ± 453.3^{a}	2392 ± 137.2^{b}	2391.5 ± 316.1^{ab}	3284.5 ± 334.5^{a}	892.5 ± 197.3^{ab}	4.14 ± 0.2^{a}	76.13 ± 0.3^{a}
Agra	4638.0 ± 241.8^{a}	2276 ± 21.2^{b}	2362 ± 220.6^{ab}	2959.5 ± 94.1^{a}	683.5 ± 72.8^{ab}	4.04 ± 0.1^{a}	76.13 ± 0.1^{a}
Month 9							
Bankyehemma	4806.5 ± 451.8^{a}	1947.0 ± 17.0^{ab}	2663.0± 62.2^{b}	3197.0 ± 213.6^{a}	1053.5 ± 68.6^{ab}	3.8 ± 0.2^{a}	71.98 ± 0.0^{a}
Ampong	4145.0 ± 70.7^{a}	1997.0 ± 73.5^{ab}	2148.0± 144.3^{ab}	2548.0 ± 36.8^{a}	551.0 ±110.3^{a}	4.34 ± 0.2^{a}	75.58 ± 0.5^{a}
Agra	4131.0 ± 77.8^{a}	2143.5 ± 145.0^{ab}	2184.0 ± 94.8^{ab}	2370.5 ± 248.2^{a}	423.5 ± 231.2^{a}	3.7 ± 0.1^{a}	74.8 ± 0.6^{a}
Month 10							
Bankyehemma	4670.5 ± 451.8^{a}	2244 ± 309.7^{ab}	2426.5 ± 142.1^{ab}	3472 ± 475.2^{a}	1228 ± 165.5^{b}	3.63 ± 0.4^{a}	62.78 ± 14.0^{a}
Ampong	4148.5 ± 318.9^{a}	2095.5 ± 96.9^{ab}	2053.0 ± 415.8^{ab}	3029.5 ± 173.2^{a}	934.0 ± 76.4^{ab}	4.00 ± 0.7^{a}	73.55 ± 0.1^{a}
Agra	4078.5 ± 231.2^{a}	1728.5 ± 224.2^{a}	2350.0 ± 7.1^{ab}	2548.0 ± 267.3^{a}	819.5 ± 43.1^{ab}	3.83 ± 0.4^{a}	74.9 ± 0.6^{a}
						(min)	**(**

Values are Mean ±SD. Mean values in column under the same month with different superscript letter are significantly different (p <0.05).

Improvement of cassava is mainly based on increasing starch content and starch yield in order to ensure maximum utilization of the crop. For this reason, varieties with high starch contents and starch yield are being sought for. Starch yield is known to be affected significantly by maturity i.e. continuous aging of cassava plant (Ikegwu *et al.,* 2009). The starch yield observed from this research work ranged from 19.0025.67.00) for the various varieties at different stages of maturity. The yield of starch increased with increasing maturity. This observation was in accordance with other research on cassava starch yield (Sriroth *et al*., 1999). There were significant differences observed between the different maturities. These observations are important since starch serves as a relevant parameter for evaluation of quality starch containing foods (Huang *et al*., 2006). Harvesting of the crop is often based on starch yield.

4.2 Amylose and Amylopectin

Another important property of starch is the amylose content which can be observed in table 4.1. Low amylose contents lead to increase in the relative crystallinity of the starch which is an effect of reduced amorphous regions in the starch granule (Tukomane *et al*., 2007). The amylose content observed ranged from (14.53- 23.16) as shown in Table 4.1. The variations observed in the amylopectin and amylose content in all varieties was insignificant ($p < 0.05$), however, some differences were observed in the amylose and amylopectin contents at different maturities. This observation was in line with a study by some researchers (Liu *et al*., 2003; Huang *et al*., 2006). Amylose content of cassava ranges from 15- 25% and the amylopectin content dependents on the content of amylose in the starch. Cassava starch selection of a specific content of amylose is based on its purpose i.e. industrial or as food.

Varieties with low amylose content can be used in the production of waxy-starch (Ceballos *et al*.,) which is used in mainly in the production of adhesives and as binder whereas amylose extender mutants can be produced from those with high amylose content (Vandeputte and Delcour, 2004). From this observation, *Agra* can be used as an amylose extender whiles *bankyehemma* can be used in food industries because of its low amylose content. Amylose content of starch also affects properties such as swelling power and starch solubility of solutions made from starch, which in tend rely on the leaching of amylose from the crystalline structure of amylopectin into the solution (Moore and Amante, 2005)

4.3 Pasting Property

The viscosity of starch is important factor for starch characterization. The variations observed gave an opportunity for choosing varieties for industrial and food purposes. Table 4.2 shows the results for pasting properties of the different varieties of cassava at different maturities. It can be observed (as shown in Table 4.2) that the peak viscosity values ranged from 3904.5-4806.5. The peak viscosity was lowest for ampong and highest for bankyehemma. Trough, on the other hand, ranged from 1728.5 -2419.0 which also recorded bankyehemma as the highest and Agra as lowest. Trough viscosity indicates the ability of the starch to withstand heating and shear stress. Breakdown values observed were within 1705.5-2663.0 the highest breakdown was recorded for bankyehemaa, followed by Agra and Ampong in a descending order. The breakdown viscosities indicates the stability of the starch under heating conditions. The lowest breakdown was recorded by Ampong which shows that Ampong is more stable under heating conditions compared to Agra and

Bankyehemma. The ability of starch to form a viscous paste is determined by the final viscosity (Agriga and Iwe, 2015). The final viscosities observed ranged from 2370.53472 in all varieties. These values were low compared to the peak viscosities of the same varieties which ranged from 3904.5-4806.5. The final viscosity values and the low setback viscosities indicates that there is low tendency of the cassava starch to retrograde (Moorthy, 2002). Variety had no significant difference on yield ,amylose, amylopectin ,peak viscosity ,breakdown and peak time but had no significant difference on the trough, final viscosity, setback and pasting temperature at(p=0.05). Maturity had no significant difference on the pasting temperature, peak time and final viscosity but had a significant difference on the yield, amylose, amylopectin, peak viscosity and the trough at (p=0.05) .An observation reported earlier by (Ikegwu et al., 2009) also observed significant (P = 0.05) differences in the pasting properties of cassava starch at different harvesting times. The pasting temperatures ranged from 62.78 to 78.33 ℃ for the varieties. Bankyehemma had the lowest pasting temperature and Agra had the highest at all maturities. Higher pasting temperature is due to increase in amylose content of the starch (Novel-Cen and Betancur-Ancona, 2005). This is because of the extended escape of amylose from the amylopectin connection during starch gelatinization leading to extended swelling of the starch granules (Moorthy, 2002). The various varieties differed in terms of setback viscosity significantly (p = 0.05). Bankyehemma exhibited the highest setback viscosity of

(1228 ± 165.46) whiles Agra being the lowest had a setback viscosity value of (423.5 ± 231.22). An observation by Oduro-Yeboah *et al.* (2010) stated differences in setback viscosity which was highly significant (P = 0.05) from five analyzed cassava varieties which is similar to the present observation in this research. The peak time of the cassava varieties was between 3.7 ± 0.14^{a} minutes for *Agra* and 4.34 ± 0.19^{a} minutes for *Ampong*. Variety and maturity were observed to have no significance (p = 0.05) on the peak time which was contrary to an observation by Ikegwu *et al ;(* 2009), who observed a significant difference in the peak time of 13 improved cassava cultivars studied.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the experiment, starch yield was seen to be dependent on maturity. The yield of starch was significantly affected by the maturity stages at $p < 0.05$. In choosing a cassava for starch industry, a variety with the highest yield is sought for therefore from this investigation bankyehemma was observed to have the highest yield and hence will be recommended for starch production. The amylose content of the various cassava varieties ranged from 14 to 25%. From this work, the variety with low amylose content was bankyehemma and the highest from Agra. Therefore, bankyehemma would be highly recommended to produce waxy starch for industrial purposes whereas Agra can be used as amylose extender mutants. Pasting properties of the cassava starch were seen to be significantly affected by both variety and maturity ($p < 0.05$). Peak viscosity of the starch from bankyehemma was higher than the other varieties. This implies that bankyehemma has a higher capacity for water absorption. It will therefore require high moisture for its reconstitution. Bankyehemma‟s low breakdown indicate its stability under heating conditions, its high pasting temperature indicates high resistance towards swelling and low pasting temperature make it favorable for usage in the starch industries. Its low pasting temperature also indicate easiness in paste formation and hence appropriate for usage in many food and non-food industries because less energy is needed for its processing. Wide variations in pasting properties of the cassava varieties are indications of different applications of the various varieties.

5.2 RECOMMENDATIONS

1. From the study, *bankyehemma* will be suitable for production of starch based products because of its high starch yield.
2. Swelling properties proximate analysis and cyanide content of the three varieties should be considered for further studies

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APPENDIX

IMAGES OF EXPERIMENT

Freshly uprooted Cassava

Selected tubers for extraction

Starch obtained after extraction

Bagged starch samples for further analysis

Preparation of Solutions for Amylose and Amylopectin Determination

95% ethanol was prepared by measuring 95 ml of ethanol using a 100 ml measuring cylinder into a 100 ml volumetric flask. 5 ml of distilled water was added to the volumetric flask and its content till it reached the 100 ml mark.

1N acetic acid solution was prepared by measuring 60.05 g of acetic acid with the aid of a measuring cylinder and a mass balance into a 1 L volumetric flask. Distilled water was added to the volumetric flask till the 1 L mark was reached.

Iodine solution was prepared by measuring 0.2 g of iodine into a 100-ml volumetric flask and adding 2.0 g of potassium iodide solution. The flask was then topped up to the 100-ml mark with distilled water. 1.0 N NaOH was prepared by measuring 40 g of NaOH and dissolving it in 300 ml distilled water in a 1 L volumetric flask. Excess distilled water was added to make up to the 1 L mark.

Raw Data obtained from Analysis

YIELD

7 Month						
VARIETY	**EXTRACTION**	**WEIGHT OF BOWL (g)**	**DRIED STARCH + BOWL (g)**	**DRIED STARCH (g)**	**YIELD**	**AVERAGE (%)**
AMPONG	1	31	50	19	19	19
	2	31	50	19	19	
	3	31	50	19	19	
AGRA	1	31	50	19	19	19.66667
	2	31	51	20	20	
	3	31	51	20	20	

BANKYE HEMMA	1	121	140	19	19	19.33333
	2	135	155	20	20	
	3	137	156	19	19	

8 Month

VARIETY	**EXTRACTION**	**WEIGHT OF BOWL (g)**	**DRIED STARCH + BOWL (g)**	**DRIED STARCH (g)**	**YIELD**	**AVERAGE (%)**
AMPONG	1	31	55	24	24	23.33333
	2	31	55	24	24	
	3	31	53	22	22	
AGRA	1	31	51	20	20	21.66667
	2	31	53	22	22	
	3	31	54	23	23	
BANKYE HEMMA	1	121	145	24	24	22
	2	135	156	21	21	
	3	137	158	21	21	

9 Month

VARIETY	**EXTRACTION**	**WEIGHT OF BOWL (g)**	**DRIED STARCH + BOWL (g)**	**DRIED STARCH (g)**	**YIELD**	**AVERAGE (%)**
AMPONG	1	31	56	25	25	24.666667
	2	31	56	25	25	
	3	31	55	24	24	
AGRA	1	31	54	23	23	23.333333
	2	31	55	24	24	

	3	31	54	23	23	
BANKYE HEMMA	1	121	146	25	25	25
	2	135	161	26	26	
	3	137	161	24	24	

10 Month						
VARIETY	**EXTRACTION**	**MASS OF BOWL (g)**	**DRIED STARCH + BOWL (g)**	**DRIED STARCH (g)**	**YIELD**	**AVERAGE (%)**
AMPONG	1	31	56	25	25	25
	2	31	56	25	25	
	3	31	56	25	25	
AGRA	1	31	54	23	23	23.667
	2	31	55	24	24	
	3	31	55	24	24	
BANKYE HEMMA	1	121	147	26	26	25.667
	2	135	161	26	26	
	3	137	162	25	25	

$$\text{Yield} = \frac{mass\ of\ (Dried\ starch+bowl) - mass\ of\ bowl}{Mass\ of\ wet\ starch} \times 100\%$$

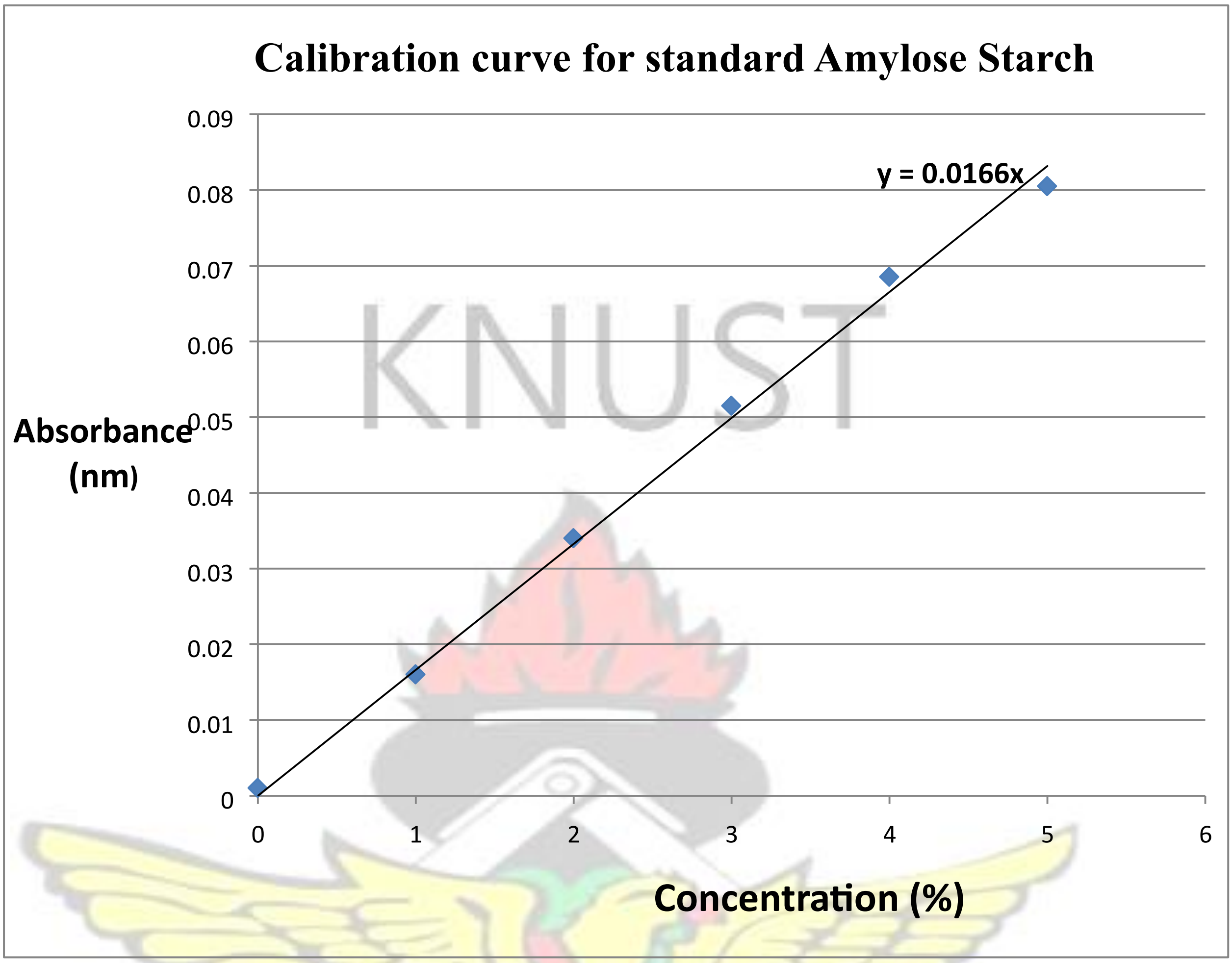
Mass of wet starch = 100 g

AMYLOSE AND AMYLOPECTIN

		STANDARD AMYLOSE
CONCENTRATION	**ABSORBANCE (620 nm)**	

	1	2	3	4	Average
1A	0.016	0.016	0.02	0.016	**0.02**
1B	0.016	0.016	0.02	0.016	
2A	0.032	0.032	0.03	0.032	**0.03**
2B	0.036	0.036	0.04	0.036	
3A	0.051	0.051	0.05	0.051	**0.05**
3B	0.052	0.052	0.05	0.052	
4A	0.068	0.068	0.07	0.068	**0.07**
4B	0.069	0.069	0.07	0.069	
5A	0.08	0.08	0.08	0.08	**0.08**
5B	0.081	0.081	0.08	0.081	

CONCENTRATION	ABSORBANCE
5	0.0805
4	0.0685
3	0.0515
2	0.034
1	0.016
0	0.001



7 month			
Varieties	**Absorbance (nm)**	**Amylose (%)**	**Amylopectin (%)**
Bankye hemma	0.24125	14.53313253	85.46686747
Ampong	0.3405	20.51204819	79.48795181
Agra	0.3845	23.1626506	76.8373494
8 month			
Varieties	**Absorbance**	**Amylose (%)**	**Amylopectin (%)**
Bankye hemma	0.3685	22.19879518	77.80120482
Ampong	0.369125	22.23644578	77.76355422
Agra	0.32875	19.80421687	80.19578313
9 month			

Varieties	Absorbance	Amylose (%)	Amylopectin (%)
Bankye hemma	0.346	20.84337349	79.15662651
Ampong	0.318	19.15662651	80.84337349
Agra	0.35	21.08433735	78.91566265
10 month			
Varieties	**Absorbance**	**Amylose (%)**	**Amylopectin (%)**
Bankye hemma	0.3225	19.42771084	80.57228916
Ampong	0.32575	19.62349398	80.37650602
Agra	0.290875	17.52259036	82.47740964

The concentration of the amylose in the starch sample was calculated from the below equation

$$A = \varepsilon L c$$

where;
A = Absorbance
$\varepsilon = molar\ Absorptivity$
L = length of Solution
c = concentration of solution

Amylose + Amylopectin = 100%

The above was used in calculating the concentration of amylopectin

Pasting Properties

7th Month							
varieties	peak	Trough	Breakdown	Final viscosity	Setback	peak time	Pasting temperature
agra	3964	2017	1947	2454	437	4.13	76.8
	4527	1995	2532	3018	1023	3.87	76.8
Ampong	4083	2211	1872	2790	579	4.47	78.35
	3726	2187	1539	2670	483	4.13	78.3
Bankye Hemma	4265	2329	1936	3091	762	4.2	73.65
	4316	2509	1807	3273	764	3.93	72.7

8th Month							
varieties	peak	Trough	Breakdown	Final viscosity	Setback	peak time	Pasting temperature
agra	4809	2291	2518	3026	735	4.07	76.2
	4467	2261	2206	2893	632	4	76.05
Ampong	4463	2295	2168	3048	753	4.27	76.3
	5104	2489	2615	3521	1032	4	75.95
Bankye Hemma	4714	2076	2638	2968	892	4.13	72.75
	4368	2121	2247	3018	897	4.2	72.65

9th Month							
varieties	peak	Trough	Breakdown	Final viscosity	Setback	peak time	Pasting temperature
agra	4186	1935	2251	2195	260	3.8	75.2
	4076	1959	2117	2546	587	3.6	74.4
Ampong	4095	2049	2046	2522	473	4.47	75.95
	4195	1945	2250	2574	629	4.2	75.2
Bankye Hemma	4660	2041	2619	3046	1005	3.93	72
	4953	2246	2707	3348	1102	3.67	71.95

10th Month							
varieties	peak	Trough	Breakdown	Final viscosity	Setback	peak time	Pasting temperature
agra	3915	1570	2345	2359	789	4.13	75.3
	4242	1887	2355	2737	850	3.53	74.5
Ampong	3923	2164	1759	3152	988	4.47	73.5
	4374	2027	2347	2907	880	3.53	73.6
Bankye Hemma	4990	2463	2527	3808	1345	3.33	52.9
	4351	2025	2326	3136	1111	3.93	72.65

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
variety	yield	1.583	2	.792	1.462	.270

	amylose	6.901	2	3.451	2.433	.130
	amylopectin	6.909	2	3.455	2.435	.130
	peak	541800.250	2	270900.125	3.384	.068
	trough	245649.083	2	122824.542	6.722	.011
maturity	yield	114.125	3	38.042	70.231	.000
	amylose	22.846	3	7.615	5.370	.014
	amylopectin	22.823	3	7.608	5.362	.014
	peak	813391.167	3	271130.389	3.387	.054
	trough	261099.667	3	87033.222	4.763	.021
variety * maturity	yield	10.750	6	1.792	3.308	.037
	amylose	89.016	6	14.836	10.462	.000
	amylopectin	88.982	6	14.830	10.453	.000
	peak	710609.083	6	118434.847	1.480	.265
	trough	335936.583	6	55989.431	3.064	.047

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
variety	Breakdown	332560.1	2	166280	2.906	0.094
	Final viscosity	1296558	2	648279.2	6.898	0.01
	Setback	461706.8	2	230853.4	8.499	0.005
	Peak time	13843.08	2	6921.542	0.991	0.4
	Pasting temp	168.601	2	84.3	5.148	0.024
maturity	Breakdown	753360.8	3	251120.3	4.388	0.026
	Final viscosity	361018.8	3	120339.6	1.281	0.325
	Setback	413712.3	3	137904.1	5.077	0.017
	Peak time	20750.36	3	6916.786	0.99	0.43
	Pasting temperature	109.514	3	36.505	2.229	0.137
variety * maturity	Breakdown	459181.9	6	76530.32	1.337	0.314
	Final viscosity	587620.7	6	97936.78	1.042	0.446
	Setback	281493.9	6	46915.65	1.727	0.198
	Peak time	41890.71	6	6981.785	0.999	0.469
	Pasting temperature	66.019	6	11.003	0.672	0.675