TITLE PAGE

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

COMPARATIVE EVALUATION OF PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF CASSAVA FLOUR FROM DIFFERENT FERTILIZER PROTOCOLS

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISRY AND BIOTECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY IN FOOD SCIENCE AND TECHNOLOGY

BY

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CERTIFICATION

I hereby declare that this thesis is the result of my own work and that, to the best of my knowledge, it contains no material previously publish by another person for the award of degree in any other University, except where acknowledgement has been made in the text

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) is a major food crop in tropical Africa. The root has the potential to bridge the food security gap in Africa. However, yield is generally low due to poor soil fertility and failure of farmers to apply fertilizer during crop cultivation. Fertilizer application to soil is a way of increasing yield of cassava root per unit area. The study was therefore conducted to investigate the flour yield, physico-chemical, functional and pasting properties of flour from *Afisiafi, Bankyehemaa* and *Dokuduade* cassava varieties under seven different fertilizer protocols and a control (no fertilizer). The cassava varieties were harvested after 10 months of maturity and processed into flour. Highest dry matter (48.79%) was recorded for *Bankyehemaa* under NPK (60-30-0) fertilizer protocol with lowest value (36.76%) for *Dokuduade* for the control. Highest flour yield (65.29%) was recorded for *Afisiafi* under *NPK* 60-30-60 and lowest (18.71%) *for Dokuduade* under NPK (30-15-15) +2.5t/ha Poultry Manure (P. M). The highest flour pH (9.95) was recorded for *Afisiafi* with NPK 60-30-30 and lowest (5.57) for *Dokuduade* with 2.5t/ha P.M. Flour pH was significantly affected ($P < 0.05$) by varietal differences and fertilizer treatments. Starch yield of flour was highest (80.26%) for *Afisiafi* under NPK (30-15-15) + 2.5t/ha P.M and lowest (49.82%) for *Bankyehemaa* under NPK (60-30-90). In terms of minerals compositions; calcium range between 779.57 and 1777.75 mg/kg, with the lowest for *Bankyehemaa* for control and highest for *Afisiafi* with 5t/ha P.M. while iron range between 5.81 and 79.29 mg/kg, lowest for *Afisiafi* for control and highest for *Afisiafi* with 5t/ha P.M. Functional properties such as water binding capacity recorded lowest (91.83%) for *Bankyehemaa* under NPK (60-30-90) and highest (144.48%) for *Bankyehemaa* under NPK (60-30-60) treatment, swelling power range between 2.62 and 10.51% for *Dokuduade* and *Afisiafi* under control and NPK (60-30-90) protocols, respectively while amylose estimation range between 10.02

and 22.52%, with lowest for *Bankyehemaa* under NPK (30-15-15) +2.5t/ha P.M. and highest for *Dokuduade* under NPK (60-30-0).

Solubility also recorded lowest of 4.72% and highest of 16.49% for *Bankyehemaa* under NPK (60-30-0) and *Afisiafi* under NPK (30-15-15) +2.5t/ha P.M protocols respectively. Pasting temperature (53.40 - 70.10 ºC), retrogradation (40.50 – 133.50 BU), breakdown viscosity (259.00 – 394.00 BU) and peak viscosity (334.50 – 657.50) were recorded for the pasting properties of the flour. The cassava flour starches exhibit round/truncated granule shapes with size range between 13.0 and 19.4µm. *Bankyehemaa* was found to have larger starch granule than *Afisiafi* and *Dokuduade.* The value obtained for the flour and starch yield show that *Afisiafi* can be used for industrial flour and starch production. *Afisiafi, Dokuduade* and *Bankyehemaa* cassava varieties are very responsive to potassium (K), however, increased amount of K decreases the dry matter content. Increasing the Level of K in the soil also decreases the starch content of flour. Depending on the characteristic used for the selection of starches and flour for industrial and domestic uses, the result obtained from the study revealed that fertilization of the soil with organic fertilizers such as poultry manure and chemical fertilizers has significant impact on the quality of cassava flour and starches.

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DEDICATION

To the Glory of God and to my beautiful wife Charlaine Ama Mensah and lovely daughter Nessa Aku-Shika Mensah.

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CHAPTER ONE

1.0 INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a Dicotyledonous perennial plant which belongs to the family *Euphorbiaceae*. It is said to have been introduced by the Portuguese from Latin America in the 16th century into tropical Africa (Nweke *et al*., 1994a). A higher percentage of matured roots of cassava serve as staple food for most people in Ghana and Africa as a whole (Bokanga, 1995), with occasional utilization of its leaves as vegetable. Industrially, cassava is processed to obtain flour or starch and the by-product serves as feed for livestock. Cassava is ranked as the 6th most important energy source in human diets on a worldwide basis and the 4th supplier of energy after rice, sugar, and maize (Heuberger, 2005). Ghana produces 3,600 tonnes per year of cassava and the country ranked the 4th leading producer of cassava in Tropical Africa (Akingbala *et al*., 2005). Optimum utilization of cassava and cassava products can be a catalyst for rural industrial development by raising income levels of farmers, processors and traders as well as ensuring the nutrition and food security status of Ghana (Plucknett *et al*., 1998; Balagopalan, 2002). In addition, cassava has become a preferred root crop because of its low labour input, capital and time required in cultivation (Topouzis, 2003). The dry weight of cassava root contains 80 to 90% carbohydrate, of which 80% is starch and the rest constitute glucose, fructose, sucrose and maltose (Tewe and Lutaladio, 2004).

Studies by Nweke (1996) reported that cassava root has the potential to bridge the food security gab in Africa. However, cassava yield is generally low due to poor soil fertility. The poor soil fertility is also accelerated by failure of farmers to apply manure or chemical fertilizers to the soil (Quansah *et al.*, 1997). Cassava root however, need enough nutrients for optimum development and yield of roots. Fertilizer application supplies the major soil nutrient such as nitrogen, phosphorus and potassium needed for plant growth. Addition of these soil nutrients will translate to starch synthesis and expressed in variation of starch and flour quality. Lombin *et al*. (1991) reported that the composite application of organic manure and chemical fertilizers has proven to be the most effective soil fertility management strategy in the world. High crop yield could also be achieved with balanced NPK fertilization and organic matter application (Makinde *et al*., 2001a; Bayu *et al*., 2006). While Potassium (K) salt influence the formation of starch, Nitrogen (N) and Phosphorus (P) are important for root growth. However, greater percentage of nitrogen in the soil results in excessive vegetative growth without a corresponding increase in cassava roots production.

Cassava flour is obtained by milling of dried matured cassava root (Ihedioha *et al*., 1995). Currently, research on cassava is centered on improving the quality of flour and incorporating it into other flour to make composite flour and weaning foods (AnnorFrimpong *et al*., 1996; Bokanga 1998). The characteristics of food and their products which are usually formulated with flour or starch are influenced by functional properties of the flour/starch (Ryu *et al.,* 1993). Functional properties such as viscosity of flour are important when used as gum replacers (Hong and Nip 1990). The ability of flour to form paste or gel also determines the texture and the quality of food product (Lii *et al*., 1995). Water binding capacity and solubility are also essential in determining the quality of carbohydrate-based product (Ju and Mittal, 1995). The functional and pasting properties of flour have been reported to influence gelling ability, fat and water binding ability and thus the textural quality of food products that have their substitute (Lii *et al*., 1995).

1.1 Problem Statement

Cassava is cultivated in almost all the agro-ecological zones in Ghana by peasant farmers and because it thrives well on degraded soils than most crops, farmers do not pay attention to the fertility of the soil. This is because farmers are satisfied with their minimum yield with the use of fixed inputs. Soil fertility management on farms in the tropics has been a major crop production issues due to continues land degradation and increased population growth. Also, the introduction of high yielding cassava varieties against high nutrient requirement will worsen the soil fertility problem. It is also unknown as to whether the newly introduced cassava varieties will respond to the current fertilizer levels. The same piece of land is used for cultivation over the year leading to declined fertility of the soil. The world demand for cassava root is also increasing over the years due to increased demand for industrial starch and soaring price of wheat flour for which cassava flour can be used as substitute.

Soils with inadequate nutrients are not able to supply the required plant nutrients for the synthesis of the crop and increase yield. Application of fertilizer to sustain high yields and improve quality of cassava root in production is needed.

Though studies have shown that, the addition of chemical and organic fertilizer protocols results in high yield of cassava roots, there is limited information on the effect of different fertilizer protocols on the physicochemical and functional properties of cassava flour from local cassava cultivars.

1.2 Project Justification

Current status of research in West Africa and in Ghana has focused on the production of High Quality Cassava Flour (HQCF) for use in the food industry. High quality cassava flour provides the best alternative to flour production for baked products. It has been estimated that 10% of wheat flour imports could be replaced by cassava flour. Studies have also shown that, when cassava flour is used to substitute 35% of wheat flour, a profit of 32% is achieved in terms of cost. This when harnessed can be a major source of revenue to peasant farmers and help to reduce the huge foreign exchange spent on wheat flour importation for the production of baked products. Consumption of wheat product also has health challenges. Some individual are gluten intolerant and suffer from diseases such as celiac and chronic enteropathy characterized by an inadequate immune response to the digestion of increased amount gluten from wheat consumption.

Morton (1988) reported that among the possible roots and tuber flour substitutes, cassava flour is the best choice to replace wheat flour partially due to its high yield and low cost of production. These benefits from cassava flour necessitate an exploration into the commercial production and utilization of cassava (Abass *et al*., 1998). The use of cassava flour in food products is influenced by the physicochemical, functional and the pasting properties of the flour. Fertilizer application has been shown to improve these properties. FAO (1986) remarked that, the major challenge to fertilizer use in the country is that for most crops, the fertilizer type and rate of application are not known. In addition, mineral fertilizers are barely used due to their high prices.

The knowledge on the effect of different fertilizer protocols on the quality of flours obtained from local cassava varieties will enhance the utilization of local cassava varieties. Research in many African countries has depicted that increased in cassava yield can be held for many years with adequate manure or fertilizer. In other to attain the yield potential of the crop, soil fertility and fertilizer application is required (Agbaje and Akinlosotu, 2004; Issaka *et al*., 2007).

1.3 Objective

The main objective of this study is to evaluate the quality of flour from three local cassava varieties under different fertilizer protocols.

Specific objectives are:

1. To investigate the physicochemical, functional and pasting properties of cassava flour derived from three local cassava varieties (‘*Afisiafi’, ‘Bankyehemaa’* and *‘Dokuduade*’) cultivated under seven different fertilizer protocols and a control.
2. To investigate the effect of different fertilizer protocols on the cassava flour yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botany of Cassava

Cassava (*Manihot esculenta,* Crantz) belongs to the class Dicotyledoneae, subclass *Archiclamydeae*, order *Euphorbiales*, family *Euphorbiaceae* consisting of 7,200 species. It belongs to the sub family *Manigotae* and genus *Manihot*. The genus has two edible species which are *M. utilissima* Phol (sweet cassava) and *M. aipi.* Phol (bitter cassava). The classification into sweet and bitter variety is based on the cyanogenic concentration in the root. Cassava root is the primary storage organ of the plant (Ricardo *et al*., 2007). The root is not tuberous anatomically but a true root. A mature cassava root has three major tissues: bark (periderm), peel (cortex) and parenchyma. The parenchyma regions is the edible portion of the root and constitute about 85% of the total weight with xylem vessels distributed in the matrix where starch-containing cells are found (Wheatley and Chuzel, 1993). The peel part is made up of sclerechyma and phloem, forming 11- 20% of the root weight (Alves, 2002). Three percent of the total root weight is the periderm, a thin layer with few cells thick. The size and shape of cassava root is dependent on the variety and the environmental conditions (Wheatley and Chuzel, 1993).

2.2 Origin and Domestication of Cassava

Cassava (*Manihot esculenta* Crantz) is believed to have originated in North East Brazil but there is the likelihood of other origins in Central America, Western and Southern Mexico and part of Guatemala (Rogers, 1963). The crop is said to have been cultivated in Peru and Mexico about 4000 and 2000 years ago, respectively. Cassava is a native of South

America with Brazil being its centre of origin (Doku, 1969). Pursegolve (1987) reported that, Western and Southern Mexico and parts of Guatemala and North-Eastern Brazil as the two geographical locations of phylogeny of the genus *Manihot*. Doku (1969) also expressed that the crop was first introduced to Congo in Africa from South America about 400 years ago. Cultivation of the crop has spread to about 40 African countries from

Madagascar in the South-east to Senegal and to Cape Verde in the North-west (Nweke, 2004). According to MOFA (2000), the crop was introduced to the Volta region of Ghana, where it spread to the Brong-Ahafo and Ashanti regions. It was also grown in all the Regions except the Upper East. The crop became a major food crop in the coastal belts at the beginning of the 19th century, then Ashanti and North in the prime 1930s (Doku, 1969).

2.3 Production Statistics of Cassava

World cassava production in 2009 was 242 million tonnes and Nigeria produced 45 million tons whereas Ghana produces 10 million tons (FAO, 2009). This production value is expected to rise due to the soaring prices of traded food staples, such as cereals, as farmers turn to indigenous crops as an alternative source. Among these crops cassava has been the cutting -edge because the root can be left in the ground for well over a year and harvested when food shortages arise. This attribute could lead to marked expansion in cassava output in Africa.

Table 2.1 World cassava production trend

	2006	**2007**	**2008**	**2009**
	…............................... 000 tonne………………………………..			
WORLD	**224 483**	**217 536**	**233 391**	**242 069**
Africa	**117 449**	**104 952**	**118 461**	**121 469**
Nigeria	45 721	34 410	42 770	45 000
Congo, Dem. Rep. of	14 989	15 004	15 020	15 036
Ghana	**9 638**	**9 650**	**9 700**	**10 000**
Angola	8 810	8 800	8 900	9 000
Mozambique	6 765	5 039	8 400	9 200
Tanzania, United Rep. of	6 158	6 600	6 700	6 500
Uganda	4926	4 446	4 942	4500
Malawi	2 832	3 239	3 700	4 000
Madagascar	2 359	2 400	2 405	2 000
Other Africa	15 251	15 354	15 923	16 233
Latin America	36 311	36 429	37 024	36 606
Brazil	26 639	26 541	26 600	26 000
Paraguay	4 800	5 100	5 300	5 400
Colombia	1 363	1 288	1 400	1 500
Other (Latin America)	3 509	3 500	3 680	3 706
Asia	70 465	75 882	77 631	83 715
Thailand	22 584	26 411	25 156	30 715
Indonesia	19 987	19 988	20 269	20 500
Viet Nam	7 783	7 985	8 300	8 600
India	7 620	8 429	8 959	9 200
China, mainland	7 500	7 875	8 300	8 700
Cambodia	2 182	2 215	3 604	3 275
Philippines	1 757	1 871	1 941	2 200
Other Asia	1 053	1 108	1 102	1 151
Oceania	258	272	275	280

Source: FAO (2009).

In Africa, cassava has been used as primary staple or a secondary staple food for the forest and transition zones. It has been cultivated since 1750 and is the most preferred root crop eaten by consumers (Anno-Frimpong, 1994).

In the early 1960s, Ghana was the seventh largest producer of Cassava in Africa with an annual production of 1.2 million tonnes. It increased its output to 7.2 million tonnes annually as the third largest producer in Africa after Nigeria and Congo (Nweke, 2004).The quantum of the nation's cassava is produced in the southern and the middle belt (MOFA, 1997). This constitutes barely 80% of the gross cassava production in Ghana with 20% granted to production in the Northern region. Cassava presently plays an important role in food security. The Ewes called the crop *agbeli,* meaning 'there is life'. The name delineate the grandness of the crop to the country and to the Ewes in particular who are not only the major cassava tillers but also the processors of cassava into *gari*, starch, tapioca, *kokonte* and others (Doku, 1969).

Cassava cultivation is practiced in all the agro-ecological zones in Ghana and ranked first in terms of cultivation and usage of the crop as food. It also contributes 16% of Ghana's Agricultural Gross Domestic Product (AGDP) (Safo-Kantanka, 2004). In Ghana, it is estimated that 70% of farmers grow cassava and is consumed by more than 80% of the population (Parkes, 2009). According to MOFA (2005), the average yield of the cassava in Ghana is 12.42 metric tonnes/hectare with an achievable yield of 28.0 metric tonnes/hectare. The yield may be enhanced by the application of fertilizer by farmers to provide the requisite nutrients for optimum development of the crop.

2.4 Economic Importance of Cassava

Cassava is a staple crop in Ghana with great economic importance throughout the world (El-sharkawy, 2003). It constitutes one of the most important tropical plants and ranked fourth to rice, sugar and maize in terms of carbohydrates source in the tropics (Heuberger, 2005). A 100 g cassava root provides 160 calories. It serves as an industrial crop for the production of flour, starch and animal feed. Balagopalan *et al*. (1988) indicated that under optimum conditions cassava root can yield a maximum of 250×10^3 cal/ha/day as compared to 176×10^3 cal/ha/day from rice. The crop is of great importance to peasant farmers due to its role in food security and income generation (Colvin *et al*., 2004) as well as high level of drought tolerance with some yield even under strained conditions.

2.5 Fertilizer Use in Cassava Cultivation

Cassava has assumed an industrial status in Ghana and is grown on large scale, but owing to land ownership, it is grown on the same piece of land season after season. This leads to a decline of soil fertility and yield of crop with time (Cadavid *et al*., 1998).

In conventional agriculture, cassava cultivation is normally done without any form of fertilization of the soil (Onwueme, 1978) causing low production yield. However, cassava has high requirement for potassium unlike nitrogen and phosphorus and yields are seemingly limited by low levels of potassium in the soil. The need for adequate fertilization to safeguard high cassava yield cannot be over emphasized. Nitrogen (N) and Potassium (K) are the major nutrients required for maximum top growth and tuber yield (Kang and Okeke, 1991). Maximum levels of K in the soil induce response to N fertilizers, however, excess levels of K and N nutritents leads to luxuriant growth against tuber formation (Onwueme and Charles, 1994). Phosphorus, magnesium and calcium are however needed in minimum quantity. For instance, 25 tonnes per hectare yield of the crop requires 122kg N, 27 kg P, 145 kg K, 45 kg Ca and 20 kg Mg of nutrient (Addo-Quaye *et al*., 1993).

Compound fertilizer such as NPK has paramount effect on the mineral as well as the chemical composition of the soil (Yagodin, 1984). According to Okwu (1999), compound fertilizer yield aromatic molecules, nitrogen-free and nitrogen heterocyclic six and five membered rings bridged over by -N, NH-, -CH_2 and other groups. The presence of these compounds vary from the chemical composition of the soil and make available free fatty acid and hydrocarbons which is converted by the plant to carbohydrate residues such as hexoses and pentoses and nitrogenous compounds such as peptides and amino acids. Yagodin (1984) accounted that the elemental potassium heightens the synthesis of molecular carbohydrate such as cellulose, hemicelluloses, pectin and xylans. Okwu and Awurum (2001) proposed that application of fertilizer on cassava increases root yield but might adversely affect the chemical composition of the root as well as its product such as *gari*.

Complementary organic manure and mineral fertilizers used have been demonstrated to be a profound soil fertility management strategy in many countries of the world (Lombin *et al*., 1991). Also absorption of nutrient and distribution in cassava is intimately related to the plant growth rate, which depends on soil fertility and climatic conditions as well as on varietal characteristics. In poor soil, fertilizer increases plant growth rate and nutrient absorption (Howeler, 2002). Fertilization of soil for cassava growth also increase the total dry matter and root yield by about 30% but nearly double the total absorption of phosphorus and potassium and increased that of Nitrogen by 61%. Sittibusaya *et al*. (1987) established that growing of cassava without fertilizer application leads to a steady decline in soil productivity causing a fall in the root yields.

Inorganic fertilizers alone are not very assistive for intensive agriculture due to its aggravation of soil degradation (Sharma and Mittra, 1991). Crops response to applied inorganic fertilizer depends on the amount of organic matter present. The total organic matter in the soil also reckons on the level of organic materials incorporated into the soil by natural means. This can be done through artificial means in the form of organic fertilizer (Agboola and Omueti, 1982). Lombin *et al.* (1991) stated that the use of organic manure complemented with inorganic fertilizer is the best soil fertility management strategy in our world today. Inorganic fertilizer in combination with organic matter result in higher and sustained crop yield (Kang and Balasubramanian, 1990; Palm *et al*., 1997; Makinde *et al*., 2001).

2.6 Maturity Indices

The knowledge of readiness of the tubers for harvesting is an important step in securing roots with beneficial eating quality. Delayed harvesting result in brittle tuber and loss in mealiness when cooked. This occurs as a result of remobilization of starch to sugar after accumulation of maximum starch in the tubers to help new shoot growth (NARI, 2004). The time after planting is one of the major indexes used for deciding when harvesting is done. Cassava roots are sufficiently developed at 6 to 7 month after planting while roots become woody and fibrous after 12 month of planting. However, harvesting can be retarded until processing, marketing or weather conditions become favourable (NARI, 2004). A field trail by Vichukit *et al*., (1994), indicated that starch content increases from 7-9 months of maturity, after this period starch content will depend on the rainfall condition.

Cassava can be classified based on time of maturity as either short-season variety or longseason variety. Short-season types takes 6 months to mature while the long-season types takes at least a year to mature and harvesting must be done immediately to avoid deterioration of the roots (Pursegolve,1987).

2.7 Utilization of Cassava in Ghana

Cassava root can be consumed in a number of forms. The root can be boiled and pounded into *fufu* or eaten as *ampesi* served with sauce and a protein from either meat or fish source (Dorosh, 1988). It can also be processed into *agbelima*, *akple*, *banku* and *yakayeke* or roasted and eaten as well as processed into dried fermented chips *kokonte* and *gari* (MOFA, 2000). Cassava root can also be processed into tapioca, *fufu* flour, cookies, biscuits, buns, doughnuts, bread and cakes.

Cassava serves as feed for fattening of farm animal such as cattle, pig and poultry. Industrially, cassava starch is used in the textile, pharmaceutical, cosmetics and paper industries as well as the brewing and the bakery industries (MOFA, 2000).

2.8 Starches

Starch is the principal component of cassava and it is an important raw material for food and non food industries worldwide (Mweta, 2009). It is one of the most essential products to man which served as an important component of food by providing large balance of daily calorie intake for humans and livestock. According to Lawton (2004), starch accounts for 60-70% of calorie intake of humans. Apart from the nutritive value, it serves as raw materials with application in food, feed, pharmaceutical, textile, paper and cosmetic industries. It is used in the food industry as a thickener, as a stabilizer, filler adding to the solid content of soups and as a binder to merge mass of food to prevent drying out during cooking (Burrell, 2003; Lawton, 2004). The applications of starch in food industries depend on the functional properties such as pasting, gelatinization, retrogradation, water absorption capacity, swelling power and solubility which vary based on the botanical source and variety (Yuan *et al*., 2007; Peroni *et al*., 2006; Amani *et al*., 2004).

Calcium, magnesium, phosphorus, potassium and sodium are the most common minerals found in starches, however, they are of little quantity (<0.4%) and are of little functional importance except phosphorus (Tester *et al*., 2004). Starches from root and tuber contain phosphorus in the form of mono phosphate esters which is covalently bonded to the starch. It influences the functional properties such as viscosity, paste clarity and paste stability (Jane *et al*., 1996). Lower levels of 0.0007% have been reported by Peroni *et al*. (2006) in cassava starches.

The starch yield from cassava roots is dependent but not limited to: cultivar type, maturity, extraction method, cultivation practices. Starch composition in cassava root increases with an increase in the dry matter accumulation (Henry *et al*., 1998). The starch content usually declines at the beginning of raining season due to inadequate sunlight and hence the hydrolysis of starch to sugar (Henry *et al*., 1998). Production of starch and sugar increases in cassava root when the soil has higher potassium level, as potassium help in the formation of more starch vacuoles (Addo-Quaye *et al*., 1993).

Normal starches contain 20-30% amylose, with the rest being amylopectin while high amylose starches contain more than 40% amylose and waxy starch less than 15% amylose (Van Hung *et al*., 2006; Tester *et al*., 2004). Nonetheless, the relative amylose to amylopectin content may change with crop variety (Jane *et al*., 1992; Shujun *et al., 2006*). Studies by Moorthy (2002) and Tian *et al*., (1991) reported that the amylose content of cassava ranges from 13.6-23.8%, 20-25% for sweet potato and 3-43% for cocoyam starches. Amylose content of 19.8%, 32.6% and 22.6% were also reported for cassava, yam and sweet potato starch, respectively (Peroni *et al*., 2006).

2.9 Cassava Flour

Dufour *et al*. (1996) defined cassava flour as that product obtained from cassava root as white or cream-coloured powder that does not include modified starch. Processed dry cassava flour is one form through which the tuber can have assured longevity. IITA (1990) identified that cassava flours make 45% of the essential cassava products in Africa. Abass *et al.* (1998) also stated that cassava flour is the easiest and the cheapest to make among the root crop flours and the highest source of income generator.

The flour is used in diverse ways in South India, South East Asia and Africa. Cassava flour is used in making salad dressing, biscuit, composite bread, ice cream powder, custard powder and flakes. It can also be used to make delicacies such as cassava fruit cake, cassava cake and cassava dumplings (Balagopalan *et al*., 1988). Researchers at IITA have indicated that cassava can be used to make bakery products such as cakes, cookies and doughnuts (Onabolu and Bokanga, 1995). Cassava flour is often used as substitute for cereal starch in product such as industrial adhesive (Balagopalan, 1988). Granting to IITA (2001), the starch contents of cassava flour obtained from different varieties of cassava ranged from 61.8-66.4%; however there is substantial loss in starch content of roots when left in the soil after maturity. This is because early maturing varieties are harvested at nine month after planting because only the starch component is nutritionally important to human (Ketiku and Oyenuga, 1972).

Shittu *et al*. (2008) reported that selection of cassava root variety and application of fertilizer are essential factor when considering optimizing composite cassava-wheat flour for quality bakery product.

Table 2.2: Product made by processors from cassava root and cassava flour at home, ease of production and income rating.

Product to make	Number of Commercial Processors making the product to make	Frequency of responses by processors		
		Easiest	Cheapest	Highest income generator
From cassava root:				
Cassava flour	24	13	10	11
Gari	17	0	1	1
Fufu	12	2	0	1

Lafun	11	3	3	1
Starch	7	1	0	4
Tapioca	2	0	0	0
From cassava flour:				
Chinchin	7			
Other pastries,akara, burns etc	4	0	0	0
Fish or meat pie	3	0	0	0
Doughnut	3	0	0	0
Amala	2	0	0	0
Cake		0	0	0
Semo (HQCF mixed with maize Or rice)	2	0	0	0

Source: Abass *et al*., (1998)

2.10 Functional Properties of Cassava Flour

The application of cassava flour in the food industries is influenced by its functional properties. These include water binding capacity, pasting characteristics, solubility and swelling power. The functional properties exhibited by the flour are dependent on the structural characteristics of the starch. Structural characteristics such as molecular weight of amylose and amylopectin as well as the chain length distribution of the amylopectin also contribute to the functional properties of cassava flour (Mweta, 2009).

Functional properties of flour and starch-based product are very significant when investigating their use in the food industry. This is largely due to the fact that the characteristics of food products developed from flour or starch-based products are influenced by functional properties such as viscosity, solubility and swelling power (Ryu *et al*., 1993).

Functional properties such as viscosity of flour is important in its use as gum replacers (Hong and Nip, 1990), the ability to form paste or gel also determines the texture and the quality of that food product (Lii *et al*., 1995). The water binding capacity and solubility are also essential in deciding the quality of carbohydrate-based fat substitutes (Ju and Mittal, 1995). These qualities have been reported to influence gelling ability, water and fat binding ability and hence the textual quality of food products that have their substitute.

2.11 Chemical properties of starch

Starch is a polysaccharide made up of repeating glucose unit (Cho, 1999). Starch is the main storage form of carbohydrate in plants (Vaclavik and Christain, 2008). The starch molecules occur within an organelle called amyloplast which is found in the cytoplasm. Starch consists of two molecules; a linear structure known as amylose and a branched structure known as amylopectin (Fennema, 1997). Starch granules are formed when amylose and amylopectin molecules associate themselves through hydrogen bonding. Starches obtained from different sources differ from one another in their amylose and amylopectin ratio as well as in their granule sizes and shapes.

2.11.1 Amylose

Amylose is a starch molecule composed of repeating glucose molecules linked together by α-(1→4) glycosidic linkages (Kaufman, 1989). Hegenbart (2009) reported that longer amylose molecule tend to make a product's texture fibrous because of their colligating tendencies. The elasticity of a gel is also affected by the molecular weight of the amylose.

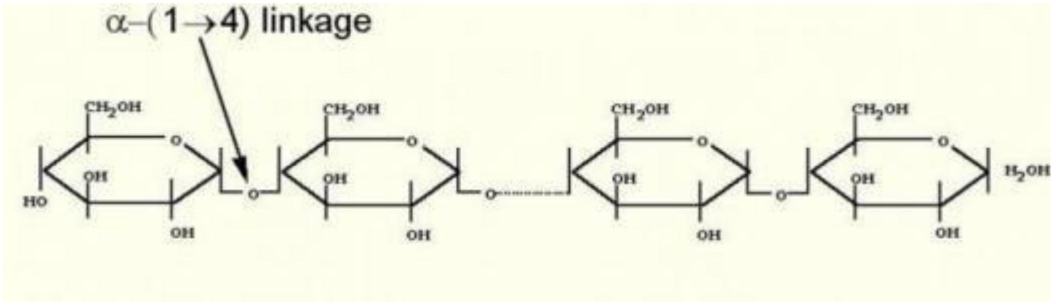


Fig 2.1 a: **Structure of amylose**.

Source: Nowjee (2004).

2.11.2 Amylopectin

Amylopectin, in which linear α-(l→4)-linked chains are interconnected through α-(l→6)linkages to form irregular branches occurring approximately one per twenty-five glucose units (Sajilata *et al*., 2006). The glucose polymers are arranged in three dimensional semicrystalline structures called a granule, having different shapes and sizes. The quantity of amylopectin in starch molecules range between 50% to 100% and starches with 100% amylose content are called waxy starches. Gallant *et al*. (1997), put forward that amylopectin granule is arranged in clusters of radially oriented chains fashioned in super helical and semi-crystalline blocks. The comparative proportion of the amylose and amylopectin present in starches are accountable for the differences in cooking characteristics exhibited in foods. Bainbridges *et al*. (1996) submitted that starches containing higher percentages of amylopectin have a higher peak viscosity and paste stability, meaning that the starch will give rise to a thicker paste which will be less probable to breakdown during cooking. Amylose is subject to form a gel and becomes cloudy when heated with water, but amylopectin stays clear when heated with water and does not gel or set a liquid.

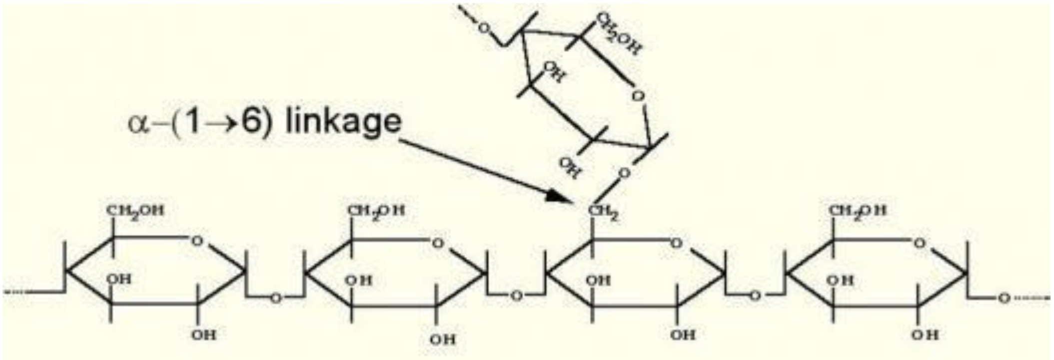


Fig 2.1b: **Structure of amylopectin**.

Source: Nowjee (2004)

2.11.3 Amylose and amylopectin ratio

Amylose and amylopectin ratio is a significant aspect of starch that determines its property and function in flour. The ratio determines the basic texture in food systems. Amylose molecule line up more readily and have extensive hydrogen bonding (Fennema, 1997) due to its linear nature. Accordingly, the bond requires more energy to break and to gelatinize the starch (Hegenbart, 2009). Generally the higher the amylose present, the higher the gelatinization temperature. This is detectable in too high amylose corn starches which require high temperature for gelatinization and therefore must be cooked under pressure. The kind of texture the gelatinized starch will build in food systems is also determined by the amylose and amylopectin ratio.

Hegenbart (2009) reported that amylose give gel strength in food systems whereas amylopectin gives high viscosity. This is because, the linear molecular structure of amylose easily align themselves with each other and link through hydrogen bonding to form gel. On the other hand, the branched amylopectin molecules cannot align easily hence, weaker hydrogen bonding and gel strength.

2.12 Functional Properties

2.12.1 Swelling Power

The Swelling power of flour render proves of the occurrence of non-covalent bonding between starch molecules. Swelling power is defined as the swollen sediment weight per weight of flour (Baah *et al*., 2009). The amylose-amylopectin ratio and chain length affect the swelling power of starches. Molecular weight distribution, degree of branching and conformation influences the degree of swelling and solubility of flour (Rickard *et al*., 1991). Sanni *et al*. (2005) reported that the swelling power of starch granules reflect the magnitude of the associative forces within the granules, thus the higher the swelling power the lower the associative forces. Swelling power is reduced by high amylose content and the presence of stronger or higher number of intermolecular bonds (Sanni *et al*., 2005). Apea-Bah *et al*. (2011) observed that the swelling power of cassava flour ranged from 17.15-31.97%. It has been found that starches with high swelling power are less resistance to break down.

2.12.2 Solubility

Solubility is expressed as the percentage by weight of flour dissolved molecularly after heating in water (Baah *et al*., 2009). Solubility of flour depends on inter-associative forces, swelling power and the presence of other components such as minerals. Cassava flour and starches have higher solubility than other tuber crop starches and this can be assigned partly to the high swelling power cassava starches experience during gelatinization

(Moorthy, 2002). Different cassava varieties have their starch solubility varying from 17.227.6%. However, Moorthy (2002) observed no direct correlation between the swelling power and solubility. The solubility of cassava flour has been found to range from 7.8118.80% (Apea-Bah *et al*., 2011). Flour with lower solubility is very important in preparation of pasta product and baked foods. High solubility flour may concede soggy dough with less cohesiveness.

2.12.3 Gelatinization of Starch

Gelatinization of starch is a procedure that breaks down the intermolecular bonds of starch molecules in the presence of water and heat, permitting the hydrogen bonding site to employ more water (Freeland-Graves and Peckham, 1987). Whenever starch granules come into contact with cold water, a small quantity of water is absorbed inducing a reversible swelling. A temporary suspension in which the granules do not dissolve is also formed. The starch inclines to settle out of the mixture as soon as the mixture is permitted to stand (Freeland-Graves and Peckham, 1987). Once the starch mixture is heated, the water starts to penetrate the starch granules, resulting in swelling and lose of birefringence. Penetration of water molecules increase the randomness in the general structure and decrease the number and size of the crystalline regions of the starch molecule. However, water entry is not allowed into the crystalline regions. Heat induces such regions to be diffused, so that the chains begin to separate into amorphous form.

Swelling is reversible to a level that the molecular structure inside the granules is disrupted and birefringence is lost. Above a relatively narrow temperature range, all the starch granules swell irreversibly and is said to have undergone gelatinization. Preceded heating of the gelatinized starch granules makes the granules to swell and soften, forming a viscous paste. When the paste is fluid, it is called a sol and when it is solid it is called a gel. The principal effect of starch granule swelling occurs when the starch is gelatinized in an aqueous medium. While the temperature of an aqueous suspension of starch is set up above the gelatinization or pasting range, hydrogen bonds go on to be disrupted, water molecules become attached to the liberated hydrogen groups and the granules swell (Mat-Hashim *et al*.,1992). Increase in viscosity of the starch paste with heating is conceived to be the cause of starch being extruded out of the starch grain into the surrounding medium. The starch molecules entrap the free water and inhibit its free flowing. The power of the starch to swell and produce a viscous paste once heated in water or with certain chemical is its most significant practical use in the food industry as it affects the texture and digestibility of starchy foods.

2.12.4 Pasting temperature and Gelatinization

Gelatinization of starch occurs over a distinct range of temperature known as gelatinization temperature. This indicates the temperature at which part of the amylose breaks from amylopectin and leaches out of the starch granules during heating. Again, the peak gelatinization or pasting temperature is the temperature at which irreversible swelling of the starch granules occur contributing to peak viscosity. Gelatinization temperature is invariably lower than the pasting temperature (Moorthy, 2002). Bainbridges and Tomlins (1996) observed that an increase in viscosity indicates the tendency of starch to retrograde or associate. They also found that starch with high pasting temperature and high peak viscosity has weak associative forces. Boakye *et al*. (2001) established that the pasting temperature of four cassava varieties usually grown in Ghana to range from 64-67 ºC. Oduro *et al*. (2000) also discovered that a related root and tuber crop, sweet potato had pasting temperature comparatively higher and ranged from 72-73.3 ºC.

According to Bainbridges *et al*. (1996), lower pasting temperature starches are easier to cook. Nevertheless, lower pasting temperature starches are as well associated with low paste stability and regarded as an undesirable property of flour. Low paste stability and low pasting temperature suggest less associative force and cross-links within the starch granules of flour.

Higher amylose indicates higher gelatinization temperature. This is as a result of the wide hydrogen bonds in the linear amylose molecules which necessitate more energy to break and gelatinize the starch (Hegenbart, 2009).

2.12.5 Paste viscosity

One essential property of starch is its ability to give viscous paste when heated in water. This property describes the use of starch in paper, textile and food industries. In a study by Moorthy (1994), using Brabender Visco-amylograph, on cassava starch from different varieties, three peak patterns were noted: Single stage gelatinization with high peak viscosity and high viscosity breakdown, two-stage gelatinization with high peak viscosity and breakdown, and Broad two-stage gelatinization with medium viscosity breakdown.

Peak viscosity is the maximum viscosity attained during the heating phase in the Brabender Visco-amylograph. At peak viscosity, the bulk of the starch granules are fully swollen. On high temperature hold phase of 95ºC, starch granules start to breakdown and solubilisation extends leading to a drop in viscosity and a trough viscosity is registered. The viscosities at 95 ºC and peak viscosity value are measures of the ability of starch to form paste upon cooking and higher value suggest thicker paste. Kim *et al*. (1995) remarked that high viscosity is suitable in food industry where high thickening is expected. The difference between the peak and trough viscosities is called breakdown.

During cooling, the solubilised starch molecules set out to re-associate and viscosity start to increase again towards the cold paste or final viscosity. When in sufficient concentration, there is formation of a gel. The deviation between the cold paste and the hot paste viscosity is known as setback or retrogradation. Amylose is the major molecule that retrograde. It can re-associate to form a harder and firmer gel again (Thomas and Atwell, 1998). Starches with higher amylopectin to amylose ratios are inclined to retrograde very much slower than starches with a high proportion of amylose. This is because of the extended period of time it takes the highly branched amylopectin molecule to re-associate in a rigorous manner (Moorthy, 2002). Retrogradation is often an undesirable side effect of starch gels and influence the overall quality and shelf life stability of food products. This constitute staling in bread and other baked products (Katayama *et al*., 2002). FreelandGraves and Peckham (1987) reported that when a cold starch gel stands for some time, there is outflow of liquid from the gel. This outflow of liquid from the gel is known as syneresis or weeping.

According to Oduro *et al*. (2000), high setback value is useful when the starch or flour is to be used for domestic product such as *fufu*, where high viscosity and paste stability at low temperature is required. Low setback value depicts that the starch or flour contributes a non-cohesive paste which is essential in many industrial application (Kim *et al*., 1995).

2.13 Sweet Potato Starch

Much research has been conducted on starches from sweet potato throughout the world. According to Moorthy (2002), sweet potato starch is an important food product in our world and the usefulness depends on the variety. The starch produce from the crop is also influenced by amylose and amylopectin ratio as well as the structure of starch (Katayama, *et al* 2002). Tsou (1992) stated that on average sweet potato granules has amylose content of about 18%. Moorthy (2002) also suggested an amylose content range of 8.5-38%, pasting temperature of 58.5-90 ºC and gelatinization temperature of 63-79 ºC. Studies by Kaur *et al*. (2006) on forms of gelatinization of sweet potato starch reported that high amylose starches have more prominent gelatinization temperature and lower enthalpy than starches with lower amylose content. Jangchud *et al*. (2003) also observed that the peak temperature of pasting in sweet potato starches varied with the starch granule size and starches with larger granules had lower pasting temperature, however, had an increase in swelling. The paste viscosity and amylose content of sweet potato were found to be inversely correlated. Sweet potato starches with lower amylose content were found to retrograde slower than those with higher amylose content (Moorthy, 2002; Collado *et al*., 1999).

2.14 Modified Cassava Starch

Cassava starch is distinctive starch which can be used in products such as foodstuffs and adhesives. The use of native starch is more common in the home than in the industry (Maneepun and Sirirojana, 1990). The starch granules from root crop swell more and easily break down and thin out when stirred, however, when chemicals are brought in, the granules cross- link and fasten the molecular network, limiting granule swelling hence stabilizing the starch past viscosity against break down (Maneepun and Sirirojana, 1990). Similar observation was made by Jensen (2009) that native starch swells rapidly and loses its viscosity during extended heating to form viscous consistent gel. This behavior of native starch makes them preferred in some applications than in others. Native starches are good texture stabilizers in food systems (Causidine, 1982), nevertheless their application is limited by low thermal resistance, thermal decomposition, shear resistance and high propensity to retrograde.

Modification of starch adjusts the properties of the starch to fit particular applications and does away with the undesirable characteristics of native starch Jensen (2009). Modification of starch therefore involves physical and chemical changes in the features of native starch to improve its functional properties (Hermansson and Svegmark, 1996). Starches are modified to increase stability to shear, heat, acid, time, cooling, freezing, change texture, decrease viscosity and to increase or decrease the time of gelatinization. Daramola and Osanyinlusi (2006) studied the effect of active component of ginger roots on starch and observed that, pasting properties of ginger modified cassava starch indicated high peak viscosity, low set back viscosity and low gelatinization time compared with native starch.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Source of Materials

Three cultivars of cassava grown with eight different fertilizer protocols were supplied by the Soil Research Institute (SRI) of the Council for Scientific and Industrial Research (CSIR), Kwadaso, in the Ashanti Region of Ghana. The designated cultivars were: *Afisiafi, Bankyehemaa* and *Dokuduade.* All the cassava varieties were harvested at 10 month of after planting. The eight different fertilizer regimes used in the experiment are Control (no fertilizer application), 2.5t/ha Poultry manure, 5t/ha Poultry manure, NPK (60-30-30), NPK (60-30-60), NPK (60-30-90), NPK (60-30-0), and NPK (30-15-15) +2.5t/ha Poultry manure.

3.2 Flour Preparation

Five kilogram of each cassava cultivar under the different fertilizer protocols were cleaned, peeled, washed and chipped and sun dried on a raised platform to constant weight and milled using a hammer mill (Schutte-Buffalo Hammer mill, NY) into flour and sieved through a 0.25 mm mesh. The flour were kept in high density polyethylene bags and stored in a freezer at 4 ºC until use.

3.3 Flour Yield

Flour yield was determined by weighing an amount of flour obtained from 5 kg of fresh cassava roots and expressed as a percentage of the fresh cassava roots.

3.4 Flour pH

Five grams of flour (dry basis) was weighed into a clean dried beaker; 20 ml of distilled water was added and stirred to obtain a homogenous mixture. The mixture was left to settle for 10 minutes. A calibrated pH meter (PHS 25, Serial No.061201, China) was immersed into the water phase of the mixture and the pH reading recorded (AACC, 2000).

3.5 Starch Yield of Flour

The starch yield of the flour was determined based on wet extraction method as described by Ellis *et al*. (2003). To 5 g of flour, 100 ml distilled water was added to dissolve the starches present in the flour. The slurry was then filtered through a cheese cloth. Excess water was added to the retentate to wash all the starch into the filtrate. The filtrate was allowed to settle for 30 min, decanted and the sediment spread on pre-weighed Petri dish. The starch sediment in the Petri dish was dried in the oven at 50^{o}C for 24 hr and weighed.

Percentage starch yield was expressed as starch recovered after extraction from 5 g flour.

3.6 Proximate Analysis

3.6.1 Moisture content

Three grams of the flour was weighed into a previously dried and weighed Petri- dish and placed in a thermostatically controlled oven at 105^{o}C for 5 hr. Samples were removed and cooled in desiccator and re-weighed. The percentage moisture content was determined by the difference in weight (AOAC 2000).

$$\% \text{ Moisture} = \frac{\text{(weight of petri-dish +flour)-(weight of petri-dish + dried flour)}}{\text{Weight of sample}} \times 100$$

3.6.2 Percentage Dry matter

Percentage dry matter content was calculated as follows:

% Dry matter = 100 - moisture content.

3.6.3 Ash content

Two grams of flour sample were transferred into a pre-ignited and pre-weighed porcelain crucible and combusted in a muffle furnace at 550 °C for 4 hr. The crucibles containing ash were cooled and re-weighed. Loss in weight was calculated as percentage ash content (AOAC, 2000). The percentage ash was calculated as stated below:

$$\text{Percentage (\%) Ash content} \quad \frac{\text{Weight of Ash}}{\text{Weight of Original sample}} \times 100$$

3.6.4 Determination of crude fiber

Two grams of flour sample was weighed into 750 ml Erlenmeyer flask and 200 ml of 1.25% H_2SO_4 was added. The flask was immediately place on a hot plate and a condenser was connected and allowed to boil for 30 min. The flask was removed and the contents immediately filtered through a cheese cloth: it was then washed with large volumes of boiling water. The washing continued until all the acid in the retentate was washed. The retentate was scraped with a spatula back into the flask and 200 ml of 1.25% NaOH solution added; the flask was contented to the condenser and boiling was resumed for another 30 min. The content of the flask was filtrated through a cheese cloth and washed with large volume of boiling water as before. The retentate was then transferred into a cleaned, dried and previously weighed crucible; the remaining particle washed from the cheese cloth into the crucible with 15 ml ethanol and dried for 2 hr at 105°C. The crucible and its content were cooled in a desiccator and reweighed (AOAC, 2000). The loss in weight was then determined and the percentage crude fiber was calculated as:

$$\% \text{ Crude fiber} = \frac{\text{loss in weight}}{\text{Initial weight of flour}} \times 100$$

3.6.5 Protein determination

Two grams of cassava flour was weighed and transferred into a digestion flask; 25 ml of concentrated H_2SO_4 solution was added with 0.5 g of selenium catalyst and the flask shaken to wet the sample. The flask was placed on a burner and digested until a clear solution was formed. The solution was then cooled at room temperature and transferred into a 100 ml volumetric flask and made to the mark.

To 250 ml conical flask, 25 ml of 2% boric acid was pipetted and two drops of mixed indicator (20 ml of bromocresol and 4 ml of methyl red) was added. The flask with its content was placed under a condenser so that the tip of the condenser was completely immersed in the solution; 10 ml of the digested sample was transferred via the stop cork of the funnel on the steam jacket into the decomposition chamber of the distillation apparatus. To the decomposition flask, 15 ml of 40% NaOH was also added. The funnel was then corked. The stop cork on the steam tap outlet was closed which forced steam into through the decomposition chamber and drove the released ammonia into the collection flask. The boric acid changed to yellow as soon as it mixed with the released ammonia; the distillation was continued for 5 min. The receiving flask was lowered so that the condenser tip was just above the liquid and washed with a little distilled water. The distillation was continued for another

30 min and the burner was removed from the steam flask. The apparatus was then flashed as was done during the digestion.

The distillate was titrated with 0.1M hydrochloric acid solution. The procedure was repeated for the blank; the titre values for the triplicate samples were recorded (AOAC, 2000) and the percentage crude protein calculated as:

$$\% \text{ Crude Protein} = \frac{100\ (A\text{-}B)}{10C} \times N \times 0.014$$

Where

A= Titre value of the sample

B= Titre value of the blank

C= weight of the sample

N= conversion factor

3.7 Determination of Functional Properties

3.7.1 Water binding capacity

The water binding capacity of cassava flour was determined according to the method described by Yamazaki (1953) and modified by Medcalf and Gilles (1965). Two grams (dry basis) of flour was weighed into a pre-weighed 50 ml centrifuge tube and 40 ml distilled water was added to form an aqueous suspension. The centrifuge tube with its content was agitated for one hour on a Griffin shaker and centrifuged at 2200 rpm for 10 min. The supernatant was decanted and the residue was drained for 10 min. The centrifuge tube with the residue was re-weighed and the percentage water binding capacity (WBC) calculated as follows:

$$\% \text{ Water binding capacity} = \frac{\text{Weight of bound water}}{\text{Weight of flour sample}} \times 100$$

3.7.2 Solubility and swelling power

One gram of flour was weighed into a 50 ml graduated centrifuge tube and 40 ml distilled water was added to form slurry. The slurry was uniformly stirred avoiding excessive speed which might lead to fragmentation of the starch granules. The slurry was heated at 85ºC in a thermostatically controlled temperature water bath for 30 min with intermittent gentle stirring. The tube was removed, dried and cooled at room temperature. It was then centrifuged at 2200 rpm for 15 min and the supernatant decanted into a cleaned, dried, preweighed Petri dish and kept in an air oven at 105ºC for at least 24 hr. The Petri dish was re-weighed and the difference in weight over the sample weight calculated to determine the solubility.

The sedimented paste in the centrifuge tube was weighed to calculate the swelling power. Solubility and Swelling power was determined based on the method by Leach *et al*., (1959). The Swelling power and percentage solubility was calculated as follows:

$$\text{Swelling power} = \frac{\text{Weight of sediment}}{\text{Weight of sample} - \text{Weight of soluble}}$$

$$\% \text{ Solubility} = \frac{\text{Weight of soluble}}{\text{Weight of sample}} \times 100$$

3.7.3 Estimation of amylose content

The formation of helical complex between amylose and iodine gives rise to the typical deep blue colour of starch dispersion stained with iodine and this forms the basis for quantitative determination of amylose content. The formation of these complexes is determined by colorimetry as described by the method of Juliano (1971). Aproximately 0.1 g of the flour sample was weighed and brushed into a100 ml volumetric flask; the sample was solubilized with 1 ml of 95% ethanol and 9 ml of 1 N sodium hydroxide. The solubilized flour was heated for 5 min in a water bath to gelatinize the starch and made up to the mark with distilled water; 1 ml of the sample was pipetted into test tubes (triplicate). To each test tube, 2 ml of 0.1 N citric acid, 1 ml iodine and 16 ml of distilled water was added. The solutions in the test tubes were vortex and allowed to stand for 20 min; absorbance was read on a spectrophotometer (Cecil CE 1021 1000 series, England) at 620 nm. The amylose content of the sample was determined in reference to a standard curve and expressed on percentage basis.

3.7.4 Pasting characteristics

The pasting characteristic of the flour samples were determined using Brabender Viscograph instrument (802526 versions 2.3.16). The moisture content of each flour sample was determined with an electronic moisture analyzer (Sartorius MA 45). The moisture value obtained was input into the software of the Brabender Viscograph, which automatically indicates the weight of flour sample to use and the amount of distilled water to be added to make slurry.

The slurry was then set into a stainless steel canister of the instrument and heated at a rate of 1.5 ºC/ min by means of thermo-regulator at a speed of 75 rpm. The start temperature was 50 ºC and when the suspension attained 95 ºC, the suspension was held constant for 15 min (first holding period) as stirring continuous. The paste was then cooled down to 50 ºC at a rate of 1.5 ºC/ min and held for another 15 min (second holding period). The process lasted for 1 hr 30 min and the following parameters were read from the print out of the Brabender Viscograph.

Pasting temperature (ºC)

Pasting time (min)

Peak viscosity (Brabender Units-BU)

Peak temperature (ºC)

Peak time (min)

Viscosity at 95 ºC (BU)

Viscosity after 15 minutes at 95 ºC (BU)

Viscosity at 50 ºC (BU)

Viscosity after 15 minute at 50 ºC (BU)

Paste stability at 50 ºC (BU)

Paste stability at 95 ºC (BU)

Setback viscosity (BU)

Breakdown viscosity (BU)

Paste stability at 95 ºC and paste stability at 50 ºC were calculated as the difference between viscosity at 95 ºC and viscosity after 15 min at 95 ºC and the difference between viscosity at 50 ºC and viscosity after 15 min at 50 ºC respectively.

3.8 Mineral Analysis

The flour samples were first ash by weighing about 2 g of the flour into clean dried crucibles. An empty crucible was added as a blank and ash in a muffle furnace for 2 hrs at 550 ºC. The crucibles were cooled for a few minutes and 3 ml of concentrated hydrochloric acid was added; the mixture was filtered and transferred into a 50 ml volumetric flask and made up to the mark with distilled water. The resulting solution was used for mineral determination.

3.8.1 Sodium and Potassium (Na^+ and K^+) determination

These were determined by flame photometry. The flame atomic spectrophotometer function on the principle that, atoms of a metal go to a state of excitation when their energy level is changed. Energy of a specific wavelength and intensity is then issued when the atom goes back to the ground state. The wavelength intensity developed by the atom in the flame is proportional to the number of atom excited in the flame and is also pro rata to the concentration of the metal in the sample. Sodium filter was employed to filter out the intensity of the light produced by the sodium in the sample mixture. A detector was used to observe the intensity of the light which indicates to a galvanometer. The same procedure was used for potassium which gives of red-violet colour and sodium a yellow colour.

3.8.2 Phosphorus (P)

Serial standards were prepared from analytical grade of KH_2PO_4. One (1ml) of colour developing reagent (CDR) (50 ml of 2.5 M H_2SO_4; 30 ml of 4 % ammonium molybdate; 15ml ascorbic acid) was added to each of the serial standards for colour development. The procedure was repeated for the sample and a blank using distilled water. The test tubes were incubated for 1 hrs 20 min at room temperature and the absorbance read from the spectrophotometer (UNICAM 929 AA, UK) at 770 nm.

3.8.3 Calcium (Ca^{2+})

Serial dilutions were prepared from analytical grade calcium chloride. A CDR was also prepare from 15 ml of 3.5 M 2- amino -2-methyl-1- propanol; 40 ml ethanediol as a buffer; 0.002 g of O-cresol phthalein coplexone; 0.1 g of 8-hydroxlquinolin and made up to the 500 ml volumetric flask mark. To 5 ml of each of the serial dilution standards of 2.0, 5.0, 10.0, 15.0 and 20.0 mg/L, 3 ml of the CDR was added and the absorbance read. The procedure was repeated for the samples and incubated at room temperature for about 30 min. The absorbance was read at 570 nm using spectrophotometer (UNICAM 929 AA, UK). It was repeated for the samples in triplicate.

3.8.4 Iron (Fe^{2+})

Serial standards were prepared using analytical grade iron (II) compound. 10 % of ascorbic acid was also made which serve to reduce any iron (III) in the sample to iron (II). About 1ml of 10 % ascorbic acid was added to 1 ml of each standards solution in the test tube and also 0.5 ml of 0.5 % of 1,10-phenanathroline. The procedure was repeated for the sample solution and then incubated at room temperature for 30 min. The absorbence was then read for triplicate sample at 520 nm.

3.9 Statistical Analysis

The General Linear Model (GLM) procedure of Minitab version 16 statistical software was used for the Analysis of Variance (ANOVA) and significant differences were reported at 95% confidence level using Tukey's test.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Proximate Composition of Cassava Flour

The dry matter content of the cassava flour is presented is Table 4.1. Dry matter is an essential chemical indicator of food quality in root and tuber crop (Assanvo *et al*., 2006). Dry matter is reported to determine the textural quality of foods (Izutsu and Wani, 1985). Among the three cassava varieties the dry matter content of *Afisiafi* ranged between 38.29 and 46.11%, with the lower limit for NPK (60-30-90) and upper limit for NPK (60-30-30) treatments. *Dokuduade* values ranged between 36.76 and 41.20%, with lower limit for control and upper limit for NPK (60-30-60) treatment. *Bankyehemaa* had values ranging between 43.14 and 48.79%, with the lower limit for NPK (30-15-15) + 2.5t/ha poultry manure (P.M) and upper limit for NPK (60-30-0) treatments. The dry mater content of the cassava were significantly affected ($p<0.05$) by the different varieties and the fertilizer protocols.

The ash content gives an expression of the mineral composition of a sample, however, contamination of a sample gives a higher concentration. Ash values in the current study, ranged between 0.65 and 2.25% for *Afisiafi*, with the lowest value for NPK (60-30-30) and highest value for NPK (60-30-90). A ranged between 0.40 and 1.28% for *Dokuduade,* with the lowest value for 2.5t/ha P.M and highest for NPK (30-15-15+ 2.5t/ha P.M). Ash content for *Bankyehemaa* also ranged between 1.04 for 5t/ha P.M and 1.30% for NPK (6030-90)

(Table 4.2). Significant difference (p<0.05) were observed among the different fertilizer protocols and the different varieties. Comparable ash values between 1.85 and 2.71% have been reported for sweet and bitter cassava (Sarkiyayi and Agar, 2010). Highest ash content of 1.73% was observed for NPK (60-30-90) treatment under the overall treatment mean, suggesting that an increased in the potassium content of the soil increased the ash content of cassava flour. According to Osagie (1992), the percentage ash in a tuber crop depends on the type of soil and moisture composition.

Protein content of flour colligate to product attributes such as appearance and texture. However, flour with lower protein content is coveted for tender or crispy food product such as snacks and cakes as flour with high protein content is coveted for products with chewy texture like bread (Wheat Marketing Centre, Inc. 2004). The crude protein content of *Afisiafi* range between 0.84% for control and 1.83% for NPK (60-30-90), *Dokudaude* values range between 0.70% for control and 1.60% for NPK (60-30-0) while that of *Bankyehemaa* had values range between 0.93% for control and 1.80% for NPK (60-30-60) treatments. Crude protein content was higher for all the different fertilizer protocols than in the control. An overall treatments mean of 1.73% was observed for NPK (60-30-90) protocols (Table 4.3). There were significant differences (p<0.05) in the protein content of the different fertilizer protocols and the different varieties, however there were nonsignificant difference (p>0.05) between *Afisiafi* and *Bankyehemaa*. The high crude protein content observed in the NPK (60-30-90) protocol was in agreement with report by Malovotta *et al*. (1955), which stated that available nitrogen in soil solution increases the protein content in cassava roots. Nitrogen fertilizer is an essential component of amino acid which is the building block of protein.

Table 4.1: Percentage Dry matter of three local cassava varieties under different fertilizer protocols

(%) Dry matter	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	43.24 (0.28)$^{c\ 1}$	36.76 (0.23)$^{e\ 2}$	43.74 (0.66)$^{d\ 1}$	41.24^{de}
2.5t/ha P. M	44.93 (0.23)$^{b\ 1}$	39.60 (0.11)$^{bc\ 3}$	43.98 (0.24)$^{cd\ 2}$	42.84^{bc}
5t/ha P.M	44.61(0.26)$^{b\ 1}$	37.72 (0.50)$^{de\ 2}$	43.87 (0.08)$^{cd\ 1}$	42.06^{cd}
NPK (60-30-30)	46.11 (0.31)$^{a\ 1}$	38.49(0.42)$^{cd\ 2}$	47.18 (0.71)$^{ab\ 1}$	43.92^{a}
NPK (60-30-60)	42.47 (0.43)$^{c\ 2}$	41.20 (0.09)$^{a\ 2}$	44.83 (0.19)$^{bcd\ 1}$	42.83^{bc}
NPK (60-30-90)	38.29 (0.06)$^{d\ 2}$	38.19(0.05)$^{cde\ 2}$	46.13 (0.93)$^{bc\ 1}$	40.87^{e}
NPK (60-30-0)	42.71 (0.29)$^{c\ 2}$	37.88 (0.27)$^{de\ 3}$	48.79 (0.56)$^{a\ 1}$	43.12^{ab}
NPK (30-15-15+ 2.5t/ha P.M)	44.36 (0.00)$^{b\ 1}$	40.00 (0.49)$^{ad\ 2}$	43.14 (0.79)$^{d\ 1}$	42.50^{bc}
Overall mean of variety	43.34^{2}	38.73^{3}	45.21^{1}	
Mean	43.34	38.73	45.21	
Min	38.29	36.76	43.14	
Max	46.11	41.20	48.79	

Mean of two replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different (p<0.05) from each other, while mean values in column that do not share a letter are significantly different (p<0.05) from each other.

Crude fiber content of *Afisiafi* range between 2.31% for control and 3.40% for NPK (60-30-60), that of *Dokuduade* range between 2.03% for control and 2.60% for NPK (60-3060) and values for *Bankyehemaa* range between 2.29 % for control and 3.35% for NPK (60-30-0) treatments. An overall treatment mean of 3.11% was observed for NPK (60-300) protocol (Table 4.4). The effect of different fertilizer protocols and the varietals differences had significant difference ($p<0.05$) on crude fiber, with non-significant difference between

Afisiafi and *Bankyehemaa* varieties. The crude fiber content of the flour compare well with literature values (3.52%) as reported by Njoku and Banigo (2000).

Table 4.2: Percentage Ash content of three local cassava varieties under different fertilizer protocols

(%) Ash Content	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	1.73 (0.14)$^{b\,1}$	0.63 (0.01)$^{d\,3}$	1.20 (0.14)$^{b\,2}$	1.19^{cd}
2.5t/ha P.M	1.58 (0.07)$^{b\,1}$	0.40 (0.07)$^{e\,2}$	1.81 (0.25)$^{a\,1}$	1.26^{bc}
5t/ha P.M	1.10 (0.06)$^{c\,1}$	0.98 (0.05)$^{bc\,1}$	1.04 (0.20)$^{b\,1}$	1.04^{d}
NPK (60-30-30)	0.65 (0.01)$^{d\,3}$	1.17 (0.13)$^{ab\,2}$	1.50 (0.10)$^{ab\,1}$	1.11^{cd}
NPK (60-30-60)	1.26 (0.06)$^{c\,1}$	0.76 (0.02)$^{d\,3}$	1.14 (0.01)$^{b\,2}$	1.05^{d}
NPK (60-30-90)	2.27(0.04)$^{a\,1}$	0.82 (0.00)$^{cd\,3}$	1.30 (0.05)$^{b\,2}$	1.47^{a}
NPK (60-30-0)	2.25 (0.04)$^{a\,1}$	0.83(0.03)$^{cd\,3}$	1.20 (0.17)$^{b\,2}$	1.43^{ab}
NPK (30-15-15+ 2.5t/ha P.M)	1.28 (0.03)$^{c\,1}$	1.28 (0.12)$^{a\,1}$	1.21 (0.29)$^{b\,1}$	1.25^{bc}
Overall mean of variety	1.51^{1}	0.86^{3}	1.30^{2}	
Mean	1.51	0.86	1.30	
Min	0.65	0.40	1.04	
Max	2.27	1.28	1.81	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Table 4.3: Percentage Crude Protein of three local cassava varieties under different fertilizer protocols

(%) Crude protein	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	0.84(0.01)$^{d\,2}$	0.70(0.04)$^{e\,3}$	0.93(0.03)$^{b\,1}$	0.83^{e}
2.5t/ha P. M	0.87(0.01)$^{d\,2}$	0.77(0.02)$^{de\,3}$	1.05(0.04)$^{b\,1}$	0.90^{de}
5t/ha P.M	0.88(0.02)$^{d\,2}$	0.81(0.04)$^{d\,2}$	1.10(0.11)$^{b\,1}$	0.93^{d}
NPK (60-30-30)	1.59(0.06)$^{c\,1}$	1.26(0.01)$^{c\,2}$	1.71(0.06)$^{a\,1}$	1.52^{c}
NPK (60-30-60)	1.72(0.03)$^{b\,1}$	1.40(0.03)$^{b\,2}$	1.80(0.04)$^{a\,1}$	1.64^{ab}
NPK (60-30-90)	1.83(0.02)$^{a\,1}$	1.57(0.01)$^{a\,2}$	1.78(0.02)$^{a\,1}$	1.73^{a}
NPK (60-30-0)	1.82(0.02)$^{a\,1}$	1.66(0.02)$^{a\,1}$	1.66(0.20)$^{a\,1}$	1.72^{ab}
NPK (30-15-15+ 2.5t/ha P.M)	1.74(0.03)$^{b\,1}$	1.40(0.03)$^{b\,2}$	1.74(0.19)$^{a\,1}$	1.62^{b}
Average mean of variety	1.41^{2}	1.20^{3}	1.47^{1}	
Mean	1.41	1.20	1.47	
Min	0.84	0.70	0.93	
Max	1.83	1.66	1.80	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Table 4.4: Percentage Crude fiber of three local cassava varieties under different fertilizer protocols

(%) Crude fiber	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	2.31(0.08)$^{d\ 1}$	2.03(0.22)$^{b\ 1}$	2.29(0.10)$^{b\ 1}$	2.21^{d}
2.5t/ha P.M	2.49(0.06)$^{cd\ 12}$	2.21(0.17)$^{ab\ 2}$	2.57(0.09)$^{b\ 1}$	2.42^{c}
5t/ha P.M	2.38(0.07)$^{d\ 12}$	2.08(0.10)$^{b\ 2}$	2.40 (0.17)$^{b\ 1}$	2.29^{cd}
NPK (60-30-30)	2.75(0.10)$^{c\ 2}$	2.28(0.13)$^{ab\ 3}$	3.25(0.12)$^{a\ 1}$	2.76^{b}
NPK (60-30-60)	3.40(0.05)$^{a\ 1}$	2.26(0.16)$^{ab\ 2}$	3.11(0.12)$^{a\ 1}$	2.92^{ab}
NPK (60-30-90)	3.32(0.05)$^{ab\ 1}$	2.42(0.09)$^{ab\ 2}$	3.33(0.13)$^{a\ 1}$	3.03^{a}
NPK (60-30-0)	3.39(0.18)$^{a\ 1}$	2.60(0.17)$^{a\ 2}$	3.35(0.25)$^{a\ 1}$	3.11^{ab}
NPK (30-15-15 +2.5t/ha P.M)	3.06(0.09)$^{b\ 1}$	2.50(0.05)$^{a\ 2}$	3.26(0.10)$^{a\ 1}$	2.94^{ab}
Overall mean of variety	2.89^{1}	2.30^{2}	2.94^{1}	
Mean	2.89	2.30	2.94	
Min	2.31	2.03	2.29	
Max	3.40	2.60	3.35	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different (p<0.05) from each other, while mean values in column that do not share a letter are significantly different (p<0.05) from each other.

4.2 Cassava Flour Yield

The flour yield of the three cassava varieties range significantly (P<0.05) between 16.57 and 65.29%. *Afisiafi* had lowest of 21.16% for control and highest of 65.29% for NPK (6030-60) treatment. *Dokuduade* had lowest value of 16.29% for NPK (60-30-30) and highest value of 56.69% for 2.5t/ha P.M treatment. *Bankyehemaa* also had lowest value of 24.34% for 5t/ha P.M and highest value of 56.72% for NPK (60-30-30) treatment (Table 4.5). Apea-Bah *et al*. (2011) obtained flour yield range between 8.0 and 23.0% for four cassava varieties from 9 to 15 month of maturity without fertilization. The same author had range between 10.6 and 14.4% flour yield at 10 month of maturity. The improved yield of between 16.57% and 65.29% as in this studies at the same 10 month of maturity, suggests a positive yield impact for fertilizer intervention. Highest flour yield was obtained from the application of 2.5t/ha of P. M for *Dokuduade*. A possible reason could be that the slow release of nutrients in poultry manure benefited the variety. *Afisiafi* cassava variety produces the highest flour yield when fertilizer interventions are employed in its cultivation. Fertilizer intervention resulted in higher cassava root yield. This outcome supports the discovering of Agbaje and Akinlosotu (2004) and Issaka *et al*., (2007) who observed higher root yield with fertilization.

4.3 Starch Yield in Cassava Flour

The starch yield of *Afisiafi* ranged between 63.06% for NPK (60-30-90) and 80.26% for NPK (30-15-15+2.5t/ha P.M) treatment. *Dokuduade* had values ranged between 50.27% for 2.5t/ha P.M and 78.97% for NPK (60-30-30) treatment, while *Bankyehemaa* had values ranged between 49.82% for NPK (60-30-90) and 70.70% for NPK (60-30-30) treatment (Table 4.6). The percentage starch yield of the flour samples from the cassava varieties under the different fertilizer protocols compare well with literature value (53.6% to 76.0%) as reported by Apea-Bah *et al*. (2011). Even though, in this study fertilizer interventions were not employed in the cultivation of the cassava. The starch yield obtained in *Afisiafi* was higher in all the treatments than that of *Dokudaude* and *Bankyehemaa*. The NPK (6030-30) treatment application recorded highest starch yield in all the three varieties given an overall mean for treatment as 75.26%. This suggests the importance of chemical fertilizer for obtaining higher starch yield. Also, the finding was in agreement with studies by (Hagens and Sittibusaya, 1990) who report that in Ghana cassava respond mainly to potassium (K).

Table 4.5: Percentage Flour yield of three local cassava varieties under different fertilizer protocols

(%) Flour Yield	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	21.16	29.41	26.73	25.77
2.5t/ha P.M	36.99	56.69	43.72	45.80
5t/ha P.M	26.45	21.55	24.34	24.11
NPK (60-30-30)	40.81	16.57	56.72	38.03
NPK (60-30-60)	65.29	28.78	45.35	46.47
NPK (60-30-90)	32.00	36.58	34.38	34.35
NPK (60-30-0)	38.77	30.60	33.05	34.14
NPK (30-15-15+ 2.5t/ha P.M)	44.57	18.71	32.66	31.98
Overall mean of variety	38.26	29.86	37.13	
Mean	38.26	29.86	37.13	
Min	21.16	16.57	24.34	
Max	65.29	56.69	56.72	

Table 4.6: Percentage Starch Yield of flour obtained from three local cassava varieties under different fertilizer protocols

(%) Starch Yield	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	70.00 (3.25)$^{bc\,1}$	50.99 (1.10)$^{d\,2}$	68.88 (2.16)^{a1}	63.29^{cd}
2.5t/ha P.M	79.14 (2.19)$^{a\,1}$	50.27 (1.69)$^{d\,3}$	67.31(2.62)$^{ab\,2}$	65.52^{cd}
5t/ha P.M	68.13 (1.53)$^{bc\,1}$	58.29 (1.69)$^{c\,3}$	62.31 (0.72)$^{b\,2}$	62.91^{d}
NPK (60-30-30)	76.11 (0.59)$^{ab\,1}$	78.97 (0.13) $^{a\,1}$	70.70 (3.41)$^{a\,2}$	75.26^{a}
NPK (60-30-60)	74.23 (2.86)$^{ab\,1}$	73.15 (1.75)$^{b\,1,2}$	67.65 (2.39)$^{ab\,2}$	71.68^{b}
NPK (60-30-90)	63.06 (1.95)$^{c\,2}$	74.89 (2.32)$^{ab\,1}$	49.82 (2.13)$^{c\,3}$	62.59^{d}
NPK (60-30-0)	69.70 (5.01)$^{bc\,1}$	62.46 (1.29)$^{c\,1}$	67.10 (1.35)$^{ab\,1}$	66.42^{c}
NPK (30-15-15+ 2.5t/ha P.M)	80.26 (3.98)$^{a\,1}$	74.11 (1.03)$^{b\,1}$	61.30 (2.30) $^{b\,2}$	71.89^{ab}
Overall mean of variety	72.58^{1}	65.39^{2}	64.36^{2}	
Mean	72.58	65.39	64.36	
Min	63.06	50.27	49.82	
Max	80.26	78.97	70.70	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different (p<0.05) from each other, while mean values in column that do not share a letter are significantly different (p<0.05) from each other.

However, increased application on K may decrease the starch yield. There were significant difference (P<0.05) between the different fertilizer protocols and the different cassava varieties, however flour starch yield for *Dokuduade* and *Bankyehemaa* were nonsignificantly different.

4.4 Mineral Composition of Cassava Flour

The calcium composition of the flour is presented in Table 4.7. Calcium content range between 1003.47 and 1777.75 mg/kg for *Afisiafi*, with the lowest value obtained for the control and the highest value for 5t/ha P.M. *Dokuduade* variety had values range between 907.98 mg/kg for control and 1496.50 mg/kg for 5t/ha P.M while that of *Bankyehemaa* had values ranging between 779.57 for control and 1260.42 mg/kg for NPK (60-30-0). An overall treatment mean of 1367.48 mg/kg was recorded for 5t/ha P.M. Lower levels of calcium were recorded for the chemical fertilizer treatments than that of the organic fertilizers. This may be attributed to the interference of phosphate (P) with calcium absorption as it forms complexes with calcium (Goodhart and Shils, 1973). There were significant differences ($p<0.05$) among the test varieties and the different protocols. Lower calcium content ranged between 33 and 30mg/100g has been reported in sweet and bitter cassava varieties (Sarkiyayi and Agar, 2010). Calcium content ranged between 260 and 535 mg/kg has also been reported in some yam varieties (Baah *et al.,* 2009). The Recommended Dietary Allowance (RDA) for calcium in an adult is about 800-1200 mg. Calcium mineral is critical for the growth of healthy bones and teeth. It is necessitated for contraction of muscles, the regulation of heartbeat and required in the formation of blood clot. Calcium also increases the permeability of the cell membrane and likewise involved in nerve impulses transmission. Less amount of calcium in an adult can lead to osteoporosis, making the bone easily brittle. The cassava flour obtained from different fertilizer intervention may lend to calcium demand in its users.

Table 4.7 Calcium composition (mg/Kg) of flour from three local cassava varieties under different fertilizer protocols

Calcium (mg/Kg)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	1003.47(44.30)$^{e\ 1}$	907.98(15.92)$^{f\ 2}$	779.51(31.82)$^{d\ 3}$	896.99^{e}
2.5t/ha P.M	1258.71(21.02)$^{d\ 1}$	1128.46(30.50)$^{c\ 2}$	1019.09(23.49)$^{bc\ 3}$	1135.42^{d}
5t/ha P.M	1777.75(15.92)$^{a\ 1}$	1496.50(46.97)$^{a\ 2}$	828.17 (23.87)$^{d\ 3}$	1367.48^{a}
NPK (60-30-30)	1387.17(26.23)$^{c\ 1}$	1053.79(21.03)$^{cd\ 3}$	1239.58(61.38)$^{a\ 2}$	1226.85^{c}
NPK (60-30-60)	1380.21(57.31)$^{c\ 1}$	1444.58(33.57)$^{a\ 1}$	908.00(43.38)$^{cd\ 2}$	1244.27^{bc}
NPK (60-30-90)	1317.71(54.34)$^{cd\ 1}$	1260.42(28.97)$^{b\ 1}$	1067.69(61.39)$^{b\ 2}$	1215.28^{c}
NPK (60-30-0)	1685.75(44.27)$^{ab\ 1}$	942.72(26.05)$^{ef\ 3}$	1260.42(76.71)$^{a\ 2}$	1296.30^{b}
NPK (30-15-15+ 2.5t/ha P.M)	1612.88(39.32)$^{b\ 1}$	1003.5(28.67)$^{de\ 2}$	1050.38(73.92)$^{bc\ 2}$	1222.25^{c}
Overall mean of variety	1427.96^{1}	1154.75^{2}	1019.11^{3}	
Mean	1427.96	1154.75	1019.11	
Min	1003.47	907.98	779.57	
Max	1777.75	1496.50	1260.42	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Table 4.8: Sodium composition (mg/Kg) of flour from three local cassava varieties under different fertilizer protocols

Sodium (mg/Kg)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	131.61(5.46)$^{f\,1}$	131.46(6.87)$^{e\,1}$	135.96(260) $^{d\,1}$	133.01^{e}
2.5t/ha P.M	227.38(4.49)$^{b\,1}$	167.43(2.60)$^{bcd\,3}$	191.41(4.50)$^{a\,2}$	195.41^{b}
5t/ha P.M	270.85(2.60)$^{a\,1}$	209.40(4.50)$^{a\,2}$	155.44(4.50)$^{c\,3}$	211.90^{a}
NPK (60-30-30)	200.40(4.50)$^{d\,1}$	158.44(2.60)$^{d\,2}$	159.74(4.51)$^{c\,2}$	172.86^{cd}
NPK (60-30-60)	146.45(4.50)$^{e\,2}$	179.42(2.60)$^{b\,1}$	174.93 (2.60)$^{b\,1}$	166.93^{d}
NPK (60-30-90)	213.89(4.49)$^{c\,1}$	155.44(4.50)$^{d\,2}$	150.94(4.50)$^{c\,2}$	173.43^{c}
NPK (60-30-0)	215.39(2.60)$^{c\,1}$	161.43(5.19)$^{cd\,2}$	155.44(4.50)$^{c\,2}$	177.42^{c}
NPK (30-15-15+ 2.5t/ha P.M)	269.35(2.60)$^{a\,1}$	173.43(4.50)$^{bc\,2}$	177.92(4.50)$^{b\,2}$	206.90^{a}
Overall mean of variety	209.42^{1}	167.06^{2}	162.72^{3}	
Mean	209.42	167.06	162.72	
Min	131.61	131.46	135.96	
Max	270.85	209.40	177.92	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Sodium (Na) content for *Afisiafi* range between 131.61 and 270.85 mg/kg, with the lowest value for the control and highest value for 5t/ha P.M. *Dokuduade* had values range between 131.46 for the control and 209.40 mg/kg for 5t/ha P.M and that of *Bankyehemaa* range between 135.96 for control and 177.92 for NPK (30-15-15)+2.5t/ha P.M. The highest of

211.90 mg/kg overall treatment mean was recorded for the 5t/ha P.M treatment (Table 4.8). There was significant difference ($p<0.05$) between the cassava varieties and the different fertilizer protocols.

Table 4.9: Potassium composition (mg/Kg) of flour from three local cassava varieties under different fertilizer protocols

Potassium (mg/Kg)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	2 019.81(21.07)$^{g\,3}$	2273.75(19.62)$^{g\,2}$	2515.26(10.54)$^{h\,1}$	2269.61^{h}
2.5t/ha P.M	3418.07(12.17)$^{d\,1}$	2388.70(14.90)$^{f\,3}$	3193.39(16.21)$^{e\,2}$	3076.48^{f}
5t/ha P.M	3874.79(21.08)$^{b\,1}$	2746.96(10.54)$^{c\,3}$	3115.00(21.07)$^{f\,2}$	3245.89^{d}
NPK (60-30-30)	3087.84(12.17)$^{e\,2}$	2701.37(12.16)$^{d\,3}$	3593.73(12.15)$^{c\,1}$	3127.65^{e}
NPK (60-30-60)	2862.99(21.07)$^{f\,3}$	3586.71(12.17)$^{a\,2}$	3825.60(12.16)$^{b\,1}$	3425.09^{c}
NPK (60-30-90)	3741.28(12.18)$^{c\,2}$	2799.75(21.08)$^{b\,3}$	4156.92(25.52)$^{a\,1}$	3565.98^{b}
NPK (60-30-0)	3428.62(13.91)$^{d\,1}$	2455.75(21.08)$^{e\,3}$	2645.16(12.14)$^{g\,2}$	2843.08^{g}
NPK (30-15-15+ 2.5t/ha P.M)	5554.10(12.16)$^{a\,1}$	2750.56(12.16)$^{c\,3}$	3411.05(21.08)$^{d\,2}$	3905.23^{a}
Overall mean of variety	3498.44^{1}	2714.22^{3}	3307.13^{2}	
Mean	3498.44	2714.22	3307.13	
Min	2019.81	2273.75	2515.26	
Max	5554.10	3586.71	4156.92	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Sodium, Na mineral is crucial for the control of water balance in the body. It also aid with muscle contraction and normal nerve impulse regulation. The RDA for sodium is between 1110 and 3300 mg, nevertheless, much consumption can be destructive to the body. The result obtained from this study shows that the use of 5t/ha P.M yield cassava flour with the highest sodium content.

The potassium (K) content of *Afisiafi* range between 2019.81 and 5554.10 mg/kg. The lowest value was recorded for the control while the highest was recorded for the NPK (3015-15) +2.5t/ha P.M. *Dokuduade* had values range between 2273.75 for the control and 3586.71 for NPK (60-30-60) and that of *Bankyehemaa* had values range between 2515.26 for the control and 4156.92 for NPK (60-30-90). The overall treatment mean also recorded highest of 3905.23 mg/kg for NPK (30-15-15) +2.5t/ha P.M (Table 4.9). Significant difference ($p<0.05$) also existed in the K content of the flour for the different protocols and the different cassava varieties. Potassium content for this study was higher than value ranged between 44 and 64 mg/kg reported in cassava starch (Mweta, 2009). This suggests that fertilizer intervention increase the potassium content of cassava flour. Onwuema (1978) also reported that cassava has high requirement for K and yield are low apparently bounded by deficiency of enough K in the soil. Adequate and safe daily intake of K is between 1875 and 5625 mg. Potassium fertilizer helps in the movement of water minerals and carbohydrates to plant tissues (Kayode, 1985).

Phosphorus (P) content of the cassava flour is presented in Table 4.10. *Afisiafi* had values range between 458.34 for the control and 1578.79 mg/kg for 5t/ha P.M. Values range between 734.84 for control and 1275.76 mg/kg for 5t/ha P.M in *Dokudaude* variety and that of *Bankyehemaa* range between 824.24 for control and 1738.64 mg/kg for 2.5t/ha P.M. Highest value of 1300.51 mg/kg was recorded for the overall treatment mean in the 2.5t/ha P.M protocol. There was significant differences ($p<0.05$) among the different protocol and the different varieties of cassava. The mineral P is noticed in majority of foods because it is an important constituent of all living organism. It combines with calcium in bone and teeth (Davidson and Stanley, 1975). Phosphorus is needed for early root formation and growth as well as to improve the quality of crop. The RDA for P in adult is about 800 mg. A range of 52 to 80 mg/100g has been reported in sweet and bitter cassava varieties (Sarkiyayi and Agar, 2010). Starches from yam are reported to contain 34 times much phosphorus as found in cassava (Moorthy, 1994). Baah *et al*. (2009) reported P ranged of 877 to 2053 mg/kg in yam varieties. The result from the study shows that when fertilizer interventions are employed the phosphorus content of cassava is enhanced. Also the used of organic manure with protocol of 2.5 and 5t/ha P.M gives better phosphorus composition in cassava flour.

The iron content obtained from cassava flour under the different fertilizer protocols is presented in Table 4.11. *Afisiafi* had values range between 5.81 for the control and 79.29 mg/kg for 5t/ha P.M. *Dokuduade* also had values range between 6.06 for the control and 44.44 mg/kg for 5t/ha P.M. and that of *Bankyehemaa* had value range between 6.53 for control and 21.21 mg/kg for NPK (60-30-60). Highest overall treatment mean of 46.97 mg/kg was recorded for 5t/ha P.M protocol. Significant differences ($p<0.05$) also existed between the different fertilizer protocol and the cassava varieties. A range of 18 to 30 mg/100g has been reported in bitter and sweet cassava varieties (Sarkiyayi and Agar, 2010). Iron is necessary for the synthesis of myoglobin and hemoglobin, which are the carriers of oxygen in the blood and muscle. The RDA for iron is 18 mg in adult.

Table 4.10: Phosphorus composition (mg/Kg) of flour from three local cassava varieties under different fertilizer protocols

Phosphorus (mg/Kg)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	458.34(19.60)$^{h\,3}$	734.84(6.94)$^{f\,2}$	824.24(13.70)$^{f\,1}$	672.48^{h}
2.5t/ha P.M	1268.94(11.44)$^{c\,2}$	893.93(21.12)$^{e\,3}$	1738.64(9.09)^{a1}	1300.51^{a}
5t/ha P.M	1578.79(19.32)$^{a\,1}$	1275.76(5.72)$^{a\,2}$	974.24(7.98)$^{d\,3}$	1276.26^{b}
NPK (60-30-30	1014.39(18.51)$^{e\,1}$	1142.42(15.46)$^{b\,2}$	961.36(9.09)$^{d\,3}$	1039.39^{e}
NPK (60-30-60)	613.64(6.81)$^{g\,3}$	1076.51(6.94)$^{c\,1}$	1055.31(7.97)$^{c\,2}$	915.15^{g}
NPK (60-30-90)	937.12(5.72)$^{f\,3}$	972.72(9.09)$^{d\,2}$	1291.67(7.95)$^{b\,1}$	1067.17^{d}
NPK (60-30-0)	1090.15(9.45)$^{d\,1}$	1047.72(6.01)$^{c\,2}$	890.91(17.16)$^{e\,3}$	1009.59^{f}
NPK(30-15-15+ 2.5t/ha P.M)	1487.12(16.75)$^{b\,1}$	1243.79(10.25)$^{a\,2}$	840.15(11.66)$^{f\,3}$	1193.68^{c}
Overall mean of variety	1056.06^{2}	1049.72^{2}	1072.07^{1}	
Mean	1056.06	1049.72	1072.07	
Min	458.34	734.84	824.24	
Max	1578.79	1275.76	1738.64	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Table 4.11: Iron composition (mg/Kg) of flour from three local cassava varieties under different fertilizer protocols

Iron (mg/Kg)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	5.81(1.58)$^{g\,1}$	6.06(0.76)$^{e\,1}$	6.53(1.58)$^{d\,1}$	6.14^{f}
2.5t/ha P.M	17.17(1.91)$^{f\,1}$	6.31(1.90)$^{e\,3}$	11.11(1.57)$^{cd\,2}$	11.53^{e}
5t/ha P.M	79.29(3.89)$^{a\,1}$	44.44(1.91)$^{a\,2}$	17.17(1.90)$^{a\,3}$	46.97^{a}
NPK (60-30-30)	55.56(1.91)$^{b\,1}$	26.01(2.32)$^{c\,2}$	21.21(1.52)$^{a\,2}$	34.26^{b}
NPK (60-30-60)	35.86(1.16)$^{d\,1}$	12.35(2.30)$^{d\,2}$	11.62(1.58)$^{bc\,2}$	19.94^{d}
NPK (60-30-90)	42.42(1.51)$^{c\,1}$	11.87(1.16)$^{d\,3}$	19.95(1.58)$^{a\,2}$	24.75^{c}
NPK (60-30-0)	9.85(1.52)$^{g\,2}$	33.58(2.66)$^{b\,1}$	10.35(1.91)$^{cd\,2}$	17.92^{d}
NPK (30-15-15+ 2.5t/ha P.M)	29.55(0.76)$^{e\,2}$	34.59(1.91)$^{b\,1}$	16.41(1.91)$^{ab\,3}$	26.85^{c}
Overall mean of variety	34.43^{1}	21.90^{2}	14.30^{3}	
Mean	34.43	21.90	14.30	
Min	5.81	6.06	6.53	
Max	79.29	44.44	21.21	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

4.5 Physicochemical and Functional Properties of Cassava Flour

Studying the physicochemical properties is crucial for food processing and quality due to their influence on the functionality of products (Gerard *et al*., 2001). Application of flour in industries is mainly governed by its functional properties. Flour pH is an important parameter in determining the quality of cassava flour. Flour pH of 4 or less indicates appreciable fermentation and starch breakdown. Fermented flour also impact a characteristic aroma and flavor to the flour making it less preferred in baking (Apea-Bah *et al*., 2011). According to Niba *et al*. (2001), low flour pH may give an indication of mould and their metabolite concentration in the flour. Flours with increased pH are also used to make flat bread Khaniki *et al*., (2007).

The flour pH range between 6.07 and 9.96 for *Afisiafi*, lowest value for NPK (60-30-60) and highest value for NPK (60-30-30) treatments. *Dokuduade* had values range between 5.57 and 8.50, with lowest value for 2.5t/ha poultry manure and highest value for 5t/ha P.M treatments, *Bankyehemaa* had values range between 6.25 and 8.64, with the lowest for NPK (60-30-90) and highest for control treatment (Table 4.12). Cassava flour pH was also significantly affected ($p<0.05$) by the different fertilizer protocols and different cassava varieties. Apea-Bah *et al*. (2011), recorded flour pH range between 5.07 and 6.65 when fertilization was not employed. Flour pH values obtained in this work was higher than those reported in literature. This may be attributed to the fertilizer intervention used in the study. Starches/flour with high pH has been noticed to increase solubility. This is as a result of increased hydrophilic role of starch at high pH values (Adebowale *et al*., 2005). Again, pH value between 5 and 7 are reported to stimulate retrogradation because of the absence of salts of monovalent anions and cations (Chen *et al*., 2011).

Table 4.12: Flour pH obtained from three local cassava varieties under different fertilizer protocols.

Flour pH	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	8.23 (0.04) $^{d\,2}$	6.53 (0.01) $^{d\,3}$	8.64 (0.07) $^{a\,1}$	7.80^{b}
2.5t/ha P.M	6.97 (0.06) $^{g\,2}$	5.57 (0.02) $^{f\,3}$	8.47 (0.17) $^{a\,1}$	7.00^{d}
5t/ha P.M	9.21 (0.02) $^{b\,1}$	8.50 (0.07) $^{a\,2}$	6.33 (0.00) $^{f\,3}$	8.01^{a}
NPK (60-30-30)	9.96 (0.01) $^{a\,1}$	6.87 (0.10) $^{c\,2}$	7.25 (0.01) $^{c\,2}$	8.02^{a}
NPK (60-30-60)	6.07 (0.01) $^{h\,3}$	6.56 (0.01) $^{d\,2}$	6.60 (0.02) $^{e\,1}$	6.41^{e}
NPK (60-30-90)	8.43 (0.01) $^{c\,1}$	6.22 (0.00) $^{e\,3}$	6.25 (0.00) $^{f\,2}$	6.97^{d}
NPK (60-30-0)	7.55 (0.04) $^{f\,1}$	6.82 (0.01) $^{c\,3}$	6.99 (0.03) $^{d\,2}$	7.12^{c}
NPK (30-15-15+ 2.5t/ha P.M)	7.78 (0.06) $^{e\,2}$	7.67 (0.05) $^{b\,3}$	7.94 (0.11) $^{b\,1}$	7.79^{b}
Overall mean of variety	8.02^{1}	6.84^{3}	7.31^{2}	
Mean	8.02	6.84	7.31	
Min	6.07	5.57	6.25	
Max	9.96	8.50	8.64	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

The Water Binding Capacity (WBC) ranged between 97.79 and 119.36% in *Afisiafi* cassava variety with the lowest for NPK (30-15-15) +2.5t/ha P.M and highest for 5t/ha P.M. A range of 97.08 to 122.75% was also obtained for *Dokuduade*, with the lowest for NPK (30-15-15) +2.5t/ha P.M and highest for NPK (60-30-90). *Bankyehemaa* also had values range between 91.83 for NPK (60-30-90) and 144.78% for NPK (60-30-60). Overall treatment mean of 121.81% being the highest was recorded for NPK (60-30-60). There was significant differences ($p<0.05$) among the different protocol and cassava varieties, however *Afisiafi* and *Dokuduade* varieties had non-significant difference (Table 4.13). Water absorption is an essential factor that is looked at in the preparation of snack food, extruded foods and baked products (Baah *et al.*, 2009). It is also a significant functional property in the development of ready-to-eat foods as eminent water binding capacity may ensure cohesiveness of product (Kulkani *et al.,* 1996). Higher WBC values raise the unit yield of flour products. In addition, the higher the WBC, the greater the quantity of water needed to make batter or dough of a particular consistency, which is used as baking guide (Pomeranz,1971). The results from the study show no particular trend in the WBC with fertilizer interventions.

Table 4.13: Water Binding Capacity of Cassava flour from three local cassava varieties under different fertilizer protocols

(%) WBC	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	112.47 (0.47)$^{ab\ 1}$	99.70 (0.80)$^{b\ 2}$	113.29 (0.87)$^{bc\ 1}$	108.49^{c}
2.5t/ha P.M	110.57 (3.58)$^{bc\ 1}$	118.57(5.71)$^{a\ 1}$	119.20 (5.62)$^{bc\ 1}$	116.11^{ab}
5t/ha P.M	119.36 (2.19)$^{a\ 1}$	116.44 (3.84)$^{a\ 1}$	111.52 (5.63)$^{bc\ 1}$	115.77^{ab}
NPK (60-30-30)	117.20 (3.09)$^{ab\ 1}$	103.70 (5.29)$^{b\ 2}$	123.57 (6.58)$^{b\ 1}$	114.82^{b}
NPK (60-30-60)	104.34 (0.22)$^{cd\ 3}$	116.33 (5.03)$^{a\ 2}$	144.78 (3.63)$^{a\ 1}$	121.81^{a}
NPK (60-30-90)	118.62 (3.00)$^{a\ 1}$	122.75 (4.80)$^{a\ 1}$	91.83 (5.77)$^{d\ 2}$	111.07^{bc}
NPK (60-30-0)	112.00 (0.74)$^{ab\ 1}$	100.39 (4.34)$^{b\ 3}$	108.41 (4.19)$^{c\ 12}$	106.93^{c}
NPK (30-15-15+ 2.5t/ha P.M)	97.79 (4.50)$^{d\ 2}$	97.08 (3.06)$^{b\ 2}$	141.86 (5.43)$^{a\ 1}$	112.24^{bc}
Overall mean of Variety	111.54^{2}	109.37^{2}	119.31^{1}	
Mean	111.54	109.37	119.31	
Min	97.79	97.08	91.83	
Max	119.36	122.75	144.78	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

Swelling power for *Afisiafi* range between 7.13% for NPK (30-15-15) + 2.5t/ha P.M and

10.51% for NPK (60-30-90). *Dokuduade* had values range between 2.62 for control and 6.25% for NPK (30-15-15) + 2.5t/ha P.M, while *Bankyehemaa* values range between 2.66 for NPK (60-30-90) and 10.04% for the control. Highest of 7.65% was recorded for the overall mean for the control treatment. Significant differences ($p<0.05$) exist among the different varieties of cassava and the different fertilizer protocols (Table 4.14). Swelling power measures the hydration capacity, since the determination measures the weight of swollen starch granules and their occluded water. The food eating quality of a product is frequently connected with retention of water in swollen starch granules (Rickard *et al*., 1991). Moorthy (2002) reported that swelling power affects the eating quality of root crops and hence the starch use in industrial applications. High swelling power leads into high digestibility and ability to use the starch in varied dietary applications (Moorthy, 2002).

According to Shimelis *et al*. (2006) starch and protein interact because of their opposite charges to form inclusion complexes on gelatinization which restrain swelling. Apea- Bah *et al*. (2011) reported values ranged between 17.2 and 31.65% for cassava flour. The values obtained by Apea- Bah *et al*. (2011) are higher than what are reported in this study. This is in agreement with work by Gunaratne *et al*. (2002), who studied the effect of fertilizer on the functional properties of flour from rice varieties and found out that fertilizer decreases swelling power. The decrease in the swelling power of flour in this study may be due to the basis of protein content. (Derycke *et al*., 2005; Debet and Gidley, 2006) also stated that, granular bound proteins reduce the swelling power of starch granules. Therefore, increased of these proteins due to fertilizer intervention may have caused the reduction in swelling power of the cassava flour.

The solubility of *Afisiafi* ranged between 6.96 and 16.49% with lowest for the control and highest for NPK (30-15-15) +2.5t/ha P.M, while that of *Dokuduade* ranged between 4.96 and 7.71% with lowest for NPK (60-30-30) and highest for 2.5t/ha P.M. *Bankyehemaa* had values ranged between 4.72 and 6.36% with lowest for NPK (60-30-0) and highest for NPK (60-30-90). Flour solubility of 9.10% for NPK (30-15-15) +2.5t/ha P.M was recorded for overall treatment mean. Significant differences ($p<0.05$) existed among the cassava varieties and the different fertilizer protocols were observed (Table 4.15).

Table 4.14: Swelling power of flour from three local cassava varieties under different fertilizer protocols

(%) Swelling power	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	10.28(0.40)$^{a\ 1}$	2.62(0.07)$^{b\ 2}$	10.04(0.81)$^{a\ 1}$	7.65^{a}
2.5t/ha P.M	7.56(0.55)$^{b\ 1}$	6.07(0.71)$^{a\ 1}$	6.30(0.52)$^{b\ 1}$	6.64^{bc}
5t/ha P.M	9.40(0.89)$^{a\ 1}$	3.31(0.25)$^{b\ 2}$	9.48(0.29)$^{a\ 1}$	7.40^{ab}
NPK (60-30-30)	9.98(0.23)$^{a\ 1}$	3.56(0.42)$^{b\ 3}$	6.93(0.44)$^{b\ 2}$	6.82^{bc}
NPK (60-30-60)	9.19(0.16)$^{a\ 1}$	5.18(0.93)$^{a\ 2}$	2.91(0.62)$^{c\ 3}$	5.76^{d}
NPK (60-30-90)	10.51(0.54)$^{a\ 1}$	5.11(0.35)$^{a\ 2}$	2.66(0.43)$^{c\ 3}$	6.09^{cd}
NPK (60-30-0)	9.40(0.25)$^{a\ 1}$	6.21(0.79)$^{a\ 2}$	2.69(0.11)$^{c\ 3}$	6.10^{cd}
NPK (30-15-15+ 2.5t/ha P.M)	7.13(0.67)$^{b\ 1}$	6.25(0.18)$^{a\ 1}$	3.14(0.40)$^{c\ 2}$	5.51^{d}
Overall mean of variety	9.18^{1}	4.79^{3}	5.52^{2}	
Mean	9.18	4.79	5.52	
Min	7.13	2.62	2.66	
Max	10.51	6.25	10.04	

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different (p<0.05) from each other, while mean values in column that do not share a letter are significantly different (p<0.05) from each other.

Apea- Bah *et al*., (2011) reported flour solubility values that ranged between 7.81 and 18.80%. Solubility of cassava starch (8.86-10.11%) was reported by Mweta, (2009). The values obtained in this study compare well with values reported in literature. However, the low value recorded in this study correlate with the increase in flour pH. The solubility observed in the study does not follow a particular pattern. Bainbridges *et al*. (1996) submitted that, a starch of good quality will have low solubility and high swelling power. Starch and flour with high solubility and low swelling power suggest poor quality that will be less stable when cooked. Using this rationale, the control and 5t/ha P.M protocols for *Afisiafi* and *Bankyehemaa* yield flour that have good solubility and swelling power.

Table 4.15: Solubility of flour obtained from three local cassava varieties under different fertilizer protocols

(%) Solubility	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	6.96(0.38)$^{d\,1}$	5.43(0.20)$^{de\,2}$	5.31(0.90)$^{a\,2}$	5.90^{c}
2.5t/ha P.M	11.05(0.64)$^{c\,1}$	7.71 (0.62)$^{a\,2}$	5.83(0.73)$^{a\,3}$	8.20^{ab}
5t/ha P.M	5.41(0.04)$^{d\,1}$	5.35(0.35)$^{de\,1}$	5.60(0.96)$^{a\,1}$	5.45^{c}
NPK (60-30-30)	12.34(0.66)$^{bc\,1}$	4.96(0.24)$^{e\,2}$	5.49(0.81)$^{a\,2}$	7.60^{b}
NPK (60-30-60)	12.71(0.36) $^{bc\,1}$	6.67(0.35)$^{bc\,2}$	5.73(0.56)$^{a\,2}$	8.37^{ab}
NPK (60-30-90)	12.29(1.45)$^{bc\,1}$	7.45(0.27)$^{ab\,2}$	6.36(0.25)$^{a\,2}$	8.70^{a}
NPK (60-30-0)	14.35(1.32)$^{ab\,1}$	7.10(0.45)$^{ab\,2}$	4.72(0.32)$^{a\,3}$	8.72^{a}
NPK (30-15-15+ 2.5t/ha P.M)	16.49(0.86)$^{a\,1}$	5.98(0.05)$^{cd\,2}$	4.83(0.63)$^{a\,2}$	9.10^{a}
Overall mean of variety	11.45^{1}	6.33^{2}	5.48^{3}	

Mean	11.45	6.33	5.48
Min	6.96	4.96	4.72
Max	16.49	7.71	6.36

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

The amylose content of the flour is presented in Table 4.16. *Afisiafi* had values range between 13.65 for the control and 20.78% for NPK (60-30-30), that of *Dokuduade* range between 14.66 for 5t/ha P.M and 22.52% for NPK (60-30-0) while *Bankyehemaa* had value range between 10.02 for NPK (30-15-15) + 2.5t/ha P.M and 21.40% for 2.5t/ha P.M. Overall treatment mean of 20.54% was recorded for the NPK (60-30-30) protocol. There was significant difference ($p<0.05$) among the different protocols and the different cassava varieties. Amylose composition is an important starch property, low amylose composition starches contributes to an increased relative crystallinity of starch owing to the reduction in the amporphous regions inside the starch granule (Tukomane *et al*., 2007). Amylose is also an essential factor to attain desirable structure in products (Naivikul, 2004), and thought to influence the eating quality of starchy food like noodles as well as the sticky properties of pasta (Grant *et al*., 1993; Mestres *et al*.,1996).

In general, the higher the amylose content, the higher the gelatinization temperature. Amylose molecules possesses linear structure which line up more readily and have more extensive hydrogen bond and thus requires more energy to break the bond in order to gelatinized the starch (Hegenbart, 2009). Apea- Bah *et al*. (2011) accounted amylose content of cassava flour to range between 16.48 and 36.00% for four cassava varieties at 9 to 15 month of maturity. Rickard *et al*. (1991) also reported amylose content ranged between 13.60

and 23.80% when he studied the functional properties of starch in some cassava accession. It is observed that the highest amylose value found in this study was marginally lower than that described in literature (Apea- Bah *et al*. (2011). This may be attributed to the month of maturity of the crop in this study. However, the decreased amylose content in response to the different fertilizer protocol is in agreement with work by Hao *et al*. (2007) and Xiong *et al*. (2008) who studied the effect of nitrogen fertilizer on gain quality of rice variety. Noda *et al*. (1996) also noted little reduction in amylose content in two different types of sweet potato starches in reaction to an increase NPK fertilizer. There was no consistent trend in amylose content in the different fertilizer protocols.

Table 4.16: Percentage Amylose content of flour from three local cassava varieties under different fertilizer protocols

(%) Amylose content	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	13.65(0.11)$^{e\ 3}$	18.06(0.19)$^{cd\ 2}$	18.55(0.19)$^{c\ 1}$	16.76^{d}
2.5t/ha P.M	16.76(0.89)$^{cd\ 3}$	18.33(0.33)$^{cd\ 2}$	21.40(0.27)$^{a\ 1}$	18.83^{b}
5t/ha P.M	18.14(0.35)$^{bc\ 1}$	14.66 (0.21)$^{f\ 2}$	11.00(0.19)$^{d\ 3}$	14.60^{e}
NPK (60-30-30)	20.78(0.62)$^{a\ 1}$	20.69(0.11)$^{b\ 1}$	20.15(0.27)$^{b\ 1}$	20.54^{a}
NPK (60-30-60)	17.43(0.34)$^{bcd\ 1}$	17.40 (0.28)$^{d\ 1}$	18.63(0.93)$^{c\ 1}$	17.82^{cd}
NPK (60-30-90)	17.89 (0.26)$^{bc\ 12}$	18.60(0.70) $^{c\ 1}$	17.50(0.22)$^{c\ 2}$	18.00 ^{c}
NPK (60-30-0)	18.41(0.22)$^{b\ 2}$	22.52(0.68)$^{a\ 1}$	11.15(0.56)$^{d\ 3}$	17.36^{d}
NPK (30-15-15+ 2.5t/ha P.M)	16.35(0.66)$^{d\ 1}$	16.18(0.15)$^{e\ 1}$	10.02(0.26)$^{d\ 2}$	14.18^{e}
Overall mean of variety	17.43^{2}	18.31^{1}	16.05^{3}	
Mean	17.43	18.31	16.05	

Min	13.65	14.66	10.02
Max	20.78	22.52	21.40

Mean of three replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

4.6 Pasting Characteristics of Cassava Flour

Pasting temperature is the temperature at which permanent swelling of starch granules takes place leading to peak viscosity (Liang and King, 2003). Reaching the pasting temperature is important in ensuring swelling, gelatination and gel formation during food processing (Eke-Ejiofor and Owuno, 2012). Pasting temperature range between 53.40 and 66.70 ºC for *Afisiafi* with the lowest value for 2.5t/ha P.M and highest value for the control.

Dokuduade had values range between 67.7 for NPK (60-30-30) and 70.10 ºC for NPK (6030-60) while that of *Bankyehemaa* had values range between 61.70 for NPK (60-30-90) and 67.60 ºC for 5t/ha P.M. Overall treatment mean of 67.27 ºC was recorded for 5t/ha P.M. Pasting temperatures of flour obtained from four cassava varieties were found to range between 67.70 and 73.20 ºC from 9 to 15 month of maturity (Apea Bah *et al*., 2011).

Studies by Asare *et al*. (2010) on the pasting temperatures of starch obtained from fortythree accessions of cassava starch reported values ranged between 63.30 and 68.20 ºC at 12 month of maturity. Adomako (2009) also recorded values ranged between 53.40 and 66.00 ºC from eight cassava genotypes at two different locations. Higher pasting temperatures of (72.00 ºC - 73.3 ºC) were observed by Oduro *et al*. (2000) on seven related root and tuber crop. The results obtained in current study compare well to studies by Adomako (2009) but slightly lower to that of Apea Baah *et al*. (2011).This may be attributed to the effect of different fertilizer interventions. Bainbridge *et al*., (1996) stated that starches with lower pasting temperatures are mostly easier to cook, suggesting that *Afisiafi* and *Bankyehemaa* cassava flour will make easier cooking. The 2.5t/ha P.M protocol may also impact lower pasting temperature to cassava flour. Nonetheless, lower pasting temperature is associated with low paste stability usually considered as an undesirable functional property. Low paste temperature and past stability are suggestive of fewer associative force and crosslinks within the starch granules. Moorthy (2002) put forward that cassava starch has low pasting temperature with an average of 68 ^{o}C, hence its ability to form paste easier compare with potato starch of 72 ^{o}C (Cameron *et al*., 2007). The low pasting temperature of cassava starches is because of the low stability of the starch granule on heating making it easier to loose the molecular structure, lower pasting temperature indicate faster swelling (Novelo-Cen and Betancur-Ancona, 2005). There was also non significant differences ($p>0.05$) among the different fertilizer protocols for *Afisiafi* and *Bankyehemaa* variety. However significant differences ($p<0.05$) was observed for *Dokudaude* under the different fertilizer protocols. The pasting temperature for *Afisiafi* and *Bankyehemaa* varieties were non-significantly differences ($p>0.05$).

Table 4.17: Pasting Temperature of flour from three local cassava varieties under different fertilizer protocols

Pasting Temperature (^{o}C)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	66.70(0.14)$^{a\ 2}$	68.40(0.00)$^{c\ 1}$	66.15(0.07)$^{ab\ 3}$	67.08^{ab}
2.5t/ha P.M	53.40(2.40)$^{b\ 2}$	68.85(0.07)$^{b\ 1}$	64.90(0.00)$^{ab\ 1}$	62.38^{c}
5t/ha P.M	65.30(0.00)$^{a\ 3}$	68.90(0.14)$^{b\ 1}$	67.60(0.14)$^{a\ 2}$	67.27^{a}
NPK (60-30-30)	66.10(0.00)^{a2}	67.90(0.00)$^{d\ 1}$	65.65(0.07)$^{ab\ 3}$	66.55^{ab}
NPK (60-30-60)	66.45(0.07)$^{a\ 2}$	70.10(0.00)^{a1}	64.50(0.00)$^{ab\ 3}$	67.02^{ab}

NPK (60-30-90)	65.40(0.00)$^{a\,1}$	69.05(0.07)^{b1}	61.70(3.96)$^{b\,1}$	65.38^{b}
NPK (60-30-0)	66.00(0.00)$^{a\,2}$	68.05(0.07)^{c1}	64.60(0.00)$^{ab\,3}$	66.22^{ab}
NPK (30-15-15+ 2.5t/ha P.M)	65.20(0.00)$^{a\,2}$	68.85(0.07)^{b1}	65.00(0.00)$^{ab\,3}$	66.35^{ab}
Overall mean of variety	64.32^{2}	68.76^{1}	65.01^{2}	
Mean	64.32	68.76	65.01	
Min	53.40	67.90	61.70	
Max	66.70	70.10	67.60	

Mean of two replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different (p<0.05) from each other, while mean values in column that do not share a letter are significantly different (p<0.05) from each other.

Retrogradation viscosity in *Afisiafi* variety range between 51.00 for 2.5t/ha P.M and 118.00 BU for NPK (60-30-30), *Dokuduade* variety had values range between 56.50 for 5t/ha P.M and 121.50 BU for the control, while *Bankyehemaa* values range between 40.40 for 5t/ha P.M and 133.50 BU for the control (Table 4.18). The control treatment recorded the highest retrogradation viscosity (116.17 BU) while 5t/ha P.M fertilizer protocol recorded the lowest (65.00 BU). The result obtained for this work compares well with work by Asare *et al*. (2010) who recorded retrogradation ranged between 62.0 and 200.5 BU on forty-three accessions of cassava starches. However, the values were slightly lower as compare to Asare *et al*. (2010). This may be due to the effect of fertilizer used in this study. Kim *et al*. (1995) reported that a low retrogradation value shows that the starches give non-cohesive paste which gives much usefulness in many industrial applications, because of lower staling rate of product prepared from the flour (Adeyemi and Idowu, 1990). According to Oduro *et al*. (2000), a higher setback value is useful if the starch is to be used for domestic products such as *fufu* which require a high viscosity and paste stability at low temperature. Significant differences ($p<0.05$) exist among the cassava varieties and the different fertilizer protocols. *Afisiafi* cassava flour under the different fertilizer protocols recorded lower set back viscosity suggesting greater industrial use. (Gunaratne *et al*., 2011), reported that fertilizer affect the chain length of amylopectin which influence retrogradation and hence decreases the retrogradation of flour.

The Break down viscosity in *Afisiafi* variety range between 261.50 for NPK (60-30-30) and 384.50 BU for NPK (30-15-15) +2.5t/ha P.M. *Dokuduade* had values range between 270.50 for NPK (60-30-0) and 359.50 BU for 2.5t/ha P.M, while that of *Bankyehemaa* range between 259.00 for 5t/ha P.M and 394.00 BU for NPK (60-30-30). There was significant difference ($p<0.05$) among the cassava varieties and among the different fertilizer protocols (Table 4.19). Adebowale *et al*. (2002) suggested that the higher the break down viscosity the lower the ability of the starch sample to withstand heating and shear stress during cooking. This implies that flour obtained from *Dokuduade* cassava variety may withstand heating and shear stress compare with flour obtained from *Afisiafi* and *Bankyehemaa*. NPK (60-30-60) treatment provided the best fertilizer protocol for flour that can withstand heat and shear stress.

Peak viscosity measures the maximum viscosity reached by a sample during the heating phase. It also speculates that the starch granules ability to swell freely before physical breakdown (Singh *et al*., 2003) and this often relates to product quality. At peak viscosity, starch granules become fully swollen but intact in shape. The more starch granules available to be hydrated in a sample, the higher the peak viscosity. *Afisiafi* had peak viscosity range between 334.5 for NPK (60-30-60) and 512.50 BU for NPK (30-15-15) + 2.5t/ha P.M, while *Dokuduade* hade values range between 476.00 for NPK (60-30-0) and 605.50 BU for 5t/ha

P.M. *Bankyehemaa* had values range between 529.00 for 5t/ha P.M and 657.50 BU for NPK (60-30-30). The high peak viscosity recorded in NPK (30-15-15) + 2.5t/ha P.M for *Afisiafi* and NPK (60-30-30) for *Bankyehemaa* show a positive correlation with high starch content (Osungbaro, 1990). Also the comparatively high peak viscosity of flour from this treatment pointed that the flour could be desirable for increasing the gel strength and elasticity of flour blends. The NPK (60-30-60) fertilizer protocol recorded the lowest peak viscosity (474.83 BU) while the control recorded the highest (545.33 BU) for the overall treatment mean.

Table 4.18: Retrogradation of flour from three local cassava varieties under different fertilizer protocols

Retrogradation (BU)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	93.50(0.71)$^{b\ 2}$	121.50(4.95)$^{a\ 1}$	133.50(3.54)$^{a\ 1}$	116.17^{a}
2.5t/ha P.M	51.00(2.83)$^{e\ 3}$	98.50(0.71)$^{bc\ 2}$	125.5(4.95)$^{a\ 1}$	91.67^{c}
5t/ha P.M	98.00(0.00)$^{b\ 1}$	56.5(0.71)$^{e\ 2}$	40.50(0.71)$^{d\ 3}$	65.00^{e}
NPK (60-30-30)	118.00(2.83)$^{a\ 1}$	108.00(1.41)$^{ab\ 1,2}$	101.50 (4.95)$^{b\ 2}$	109.17^{b}
NPK (60-30-60)	65.50(2.12)$^{d\ 2}$	81.00(5.66)$^{cd\ 1}$	57.00(1.41)$^{c\ 2}$	67.83^{e}
NPK (60-30-90)	76.00(1.41)$^{c\ 1}$	64.00(4.24)$^{de\ 2}$	56.50(0.71)$^{c\ 2}$	65.50^{e}
NPK (60-30-0)	65.50(0.71)$^{d\ 3}$	80.50(2.12)$^{cd\ 2}$	94.50(0.71)$^{b\ 1}$	80.17^{d}
NPK (30-15-15+ 2.5t/ha P.M)	81.50(2.12)$^{c\ 2}$	76.50(9.19)$^{d\ 2}$	126.00(2.83)$^{a\ 1}$	94.67^{c}
Overall mean of variety	81.13^{3}	85.81^{2}	91.88^{1}	

Mean	81.13	85.81	91.88
Min	51.00	56.50	40.50
Max	118.00	121.50	133.50

Mean of two replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

There was significant differences ($p<0.05$) among the cassava varieties and the different fertilizer protocols (Table 4.19). Asare (2010) reported peak viscosity value range between 643.70 and 857.00 BU while Boakye *et al*. (2001) reported range between 445.00 and 585.00 BU for starches from four cassava varieties. Apea Bah *et al*. (2011) also reported range between 154.00 and 305.00 BU for cassava flour obtained from four different cassava varieties.

Table 4.19: Breakdown of flour from of three local cassava varieties under different fertilizer protocols

Breakdown (BU)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	276.00(0.00)$^{e\ 2}$	297.00(8.49)$^{b\ 2}$	368.50(4.95)$^{d\ 1}$	313.83^{d}
2.5t/ha P.M	325.00(7.07)$^{d\ 3}$	359.50(3.54)$^{a\ 2}$	394.00(1.41)$^{a\ 3}$	359.50^{a}
5t/ha P.M	356.50(0.71)$^{bc\ 1}$	345.5(0.71)$^{a\ 2}$	259.00(2.83)$^{f\ 3}$	320.33^{d}
NPK (60-30-30)	331.50(10.61)$^{cd\ 2}$	282.00(1.41)$^{bcd\ 3}$	390.50(2.12)$^{ab\ 1}$	334.67^{bc}
NPK (60-30-60)	261.50(3.54)$^{e\ 3}$	291.50(0.71)$^{bc\ 2}$	379.50(0.71)$^{c\ 1}$	310.83^{d}
NPK (60-30-90)	367.00(9.90)$^{ab\ 1}$	276.00(8.49)$^{cd\ 2}$	377.00(0.00)$^{cd\ 1}$	340.00^{b}
NPK (60-30-0)	349.00(5.66)$^{bcd\ 2}$	270.50(4.95)$^{d\ 3}$	382.50(0.00)$^{bc\ 1}$	334.00^{bc}
NPK (30-15-15+ 2.5t/ha P.M)	384.50(9.19)$^{a\ 1}$	278.00(1.41)$^{bcd\ 3}$	328.00(2.83)$^{e\ 2}$	330.17^{c}
Overall mean of variety	331.38^{2}	300.00^{3}	359.88^{1}	
Mean	331.38	300.00	359.88	

Min	261.50	270.50	259.00
Max	384.50	359.50	394.00

Mean of two replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

In the current study, higher value was obtained compare to that reported by Apea Bah *et al*. (2011). The higher peak viscosity noticed among the flour starches studied reflects the low amylose content in the cassava flour (Zaidul *et al*., 2007). Low amylose starches gelatinize easily with resultant leaching out of amylose and speedy increases increase in viscosity. Starches with low peak viscosity give good cooking properties (Moorthy 2002). This suggests that flour from *Afisiafi* cassava variety may give good cooking properties. Peak viscosity indicates the strength of pastes, which are form from gelatinization during processing in food applications. It also indicative of the extent of granule swelling (Laing and King, 2003).

Table 4.20: Peak Viscosity of flour from of three local cassava varieties under different fertilizer protocols.

Peak Viscosity (BU)	*Afisiafi*	*Dokuduade*	*Bankyehemaa*	Overall Treatment Mean
Control	447.00(0.00)$^{c\,3}$	578.50(4.95)^{b2}	610.50(7.78)^{b1}	545.33^{a}
2.5t/ha P.M	411.50(6.36)$^{d\,2}$	556.50(4.95)^{c1}	556.50(0.71)^{d1}	508.17^{c}
5t/ha P.M	486.00(0.00)$^{b\,3}$	605.50(0.71)^{a1}	529.00(0.00)^{e2}	540.17^{a}
NPK (60-30-30)	493.00(7.07)$^{b\,2}$	476.00(0.00)^{e2}	657.50(4.94)^{a1}	542.17^{a}
NPK (60-30-60)	334.50(0.71)$^{e\,3}$	509.50(0.71)^{d2}	580.50(2.12)^{c1}	474.83^{d}
NPK (60-30-90)	511.00(7.07)$^{a\,2}$	502.00(4.24)^{d2}	581.00(0.00)$^{c\,1}$	531.33^{b}
NPK (60-30-0)	454.00(1.41)$^{c\,3}$	479.50(0.71)^{e2}	577.50(2.12)^{c1}	503.67^{c}
NPK (30-15-15+	512.50(3.54)$^{a\,3}$	546.00(1.41)^{c2}	557.50(0.71)^{d1}	538.67^{a}

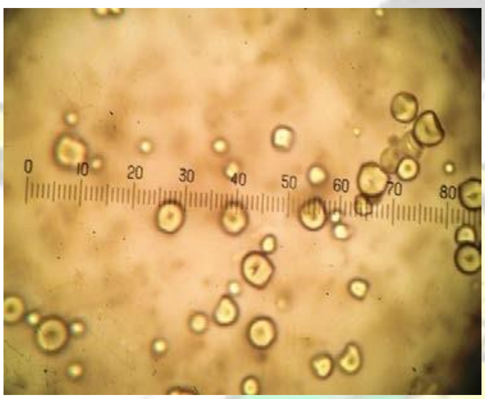
2.5t/ha P.M)			
Overall mean of variety	456.19[3]	531.69[2]	581.25[1]
Mean	456.19	531.69	581.25
Min	334.50	476.00	529.00
Max	512.50	605.50	657.50

Mean of two replicates with standard deviation in parentheses. Mean values in row that do not share a number are significantly different ($p<0.05$) from each other, while mean values in column that do not share a letter are significantly different ($p<0.05$) from each other.

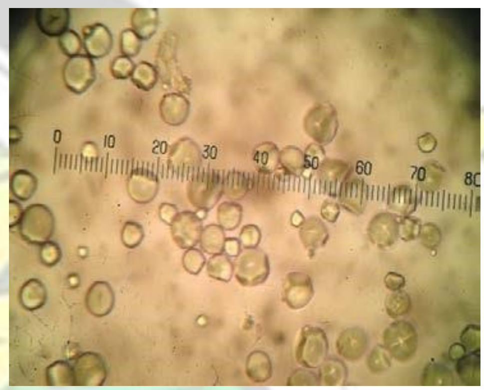
4.7 Shape and Size of Starch granule from Cassava Flour

The photographs of starch granules from cassava flour are presented in Fig 4.1. A summary of the sizes and shapes of the starch granule is provided in Table 4.21. It is presumed that starches with similar granule structure have the same behaviour hence offer a range of functional properties. Influence on granule size and shape on the functional properties may also dictate its industrial use. Sigh *et al*. (2003) revealed that starch granule contribute to gelatinization temperature, viscosity and swelling power. Starches with large granule size are said to increase swelling (Fortuna *et al*., 2000). The shape and size of granule also aid in the in the determination of suitable mesh size in the starch extraction industry (Leonel *et al*., 2003).The granular size for *Afisiafi* range between 13.0 for NPK (60-30-60) and 15.3µm for NPK (30-15-15) +2.5t/ha P.M, with an overall mean of 14.3µm. *Dokudaude* had values range between 13.9 for 2.5t/ha P.M and 16.7µm for 5t/ha P.M, with an overall mean of 14.9µm while *Bankyehemaa* values range between 15.6 for NPK (60-30-0) and 19.4µm for the control, with an overall mean of 16.7µm. The cassava starch granule size recorded in this current study compare well with those reported by Mweta (2009), who reported granule size ranged between 5.3 and 22.7µm. Values range between

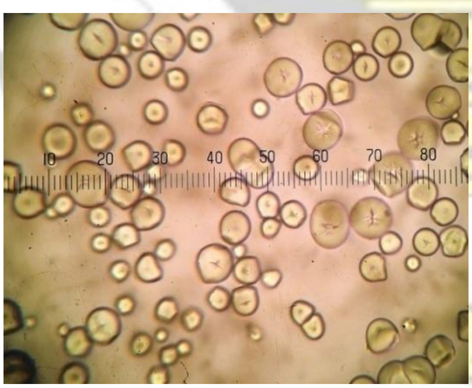
4.0 and 25.0µm have also been reported (Gunaratna and Hoover, 2002; Pérez *et al*., 2005; Mishra and Rai, 2006). The variations of the starch granule size among the different fertilizer protocol did not show any regular pattern. There was also nonsignificant difference ($p>0.05$) among *Afisiafi* and *Dokuduade* cassava varieties. The shape of the starch granule observed are mostly rounded and truncated which are similar to those observed by Mweta (2009) and Benesi (2006).



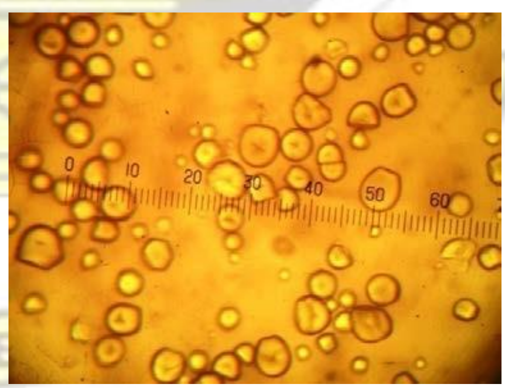
Afisiafi Control



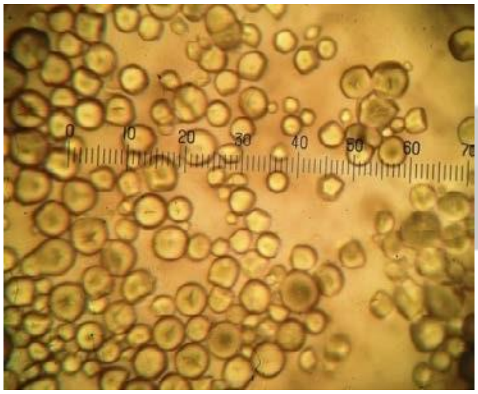
Dokuduade Control



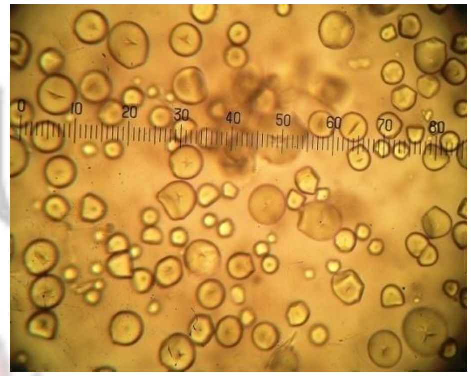
Bankyehemaa Control



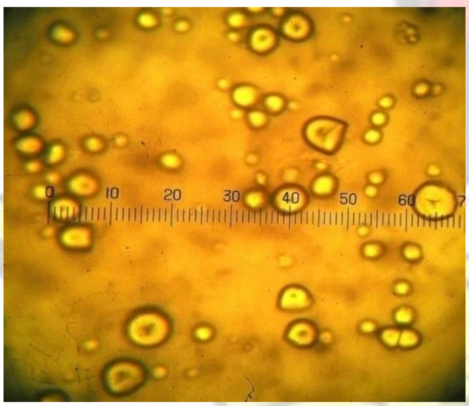
Dokuduade 2.5t/ha P.M



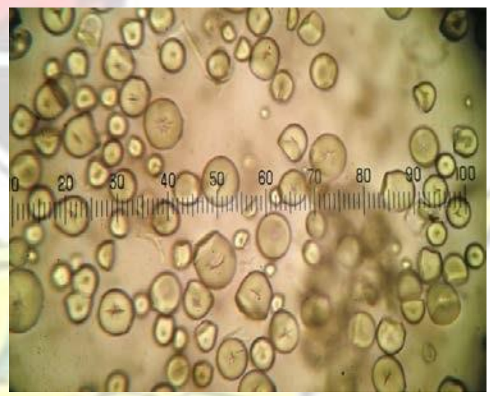
Afisiafi 2.5t/ha P.M



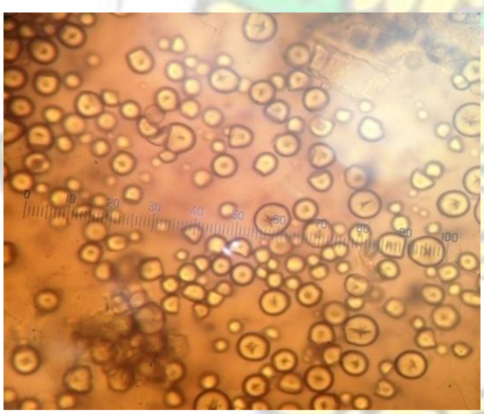
Bankyehemaa 2.5t/ha P.M



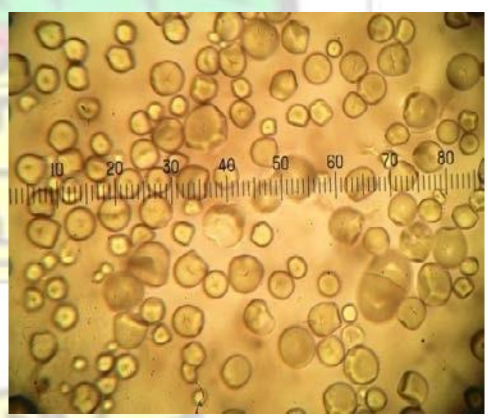
Dokuduade 5t/ha P.M



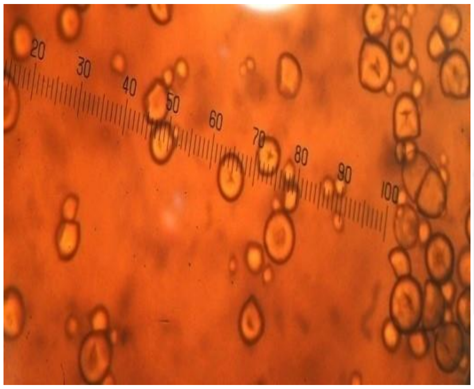
Afisiafi 5t/ha P.M



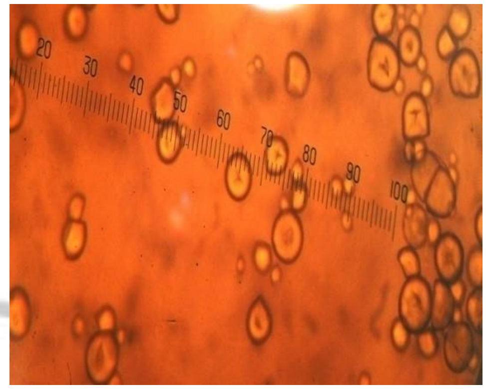
Afisiafi NPK (60-30-90)



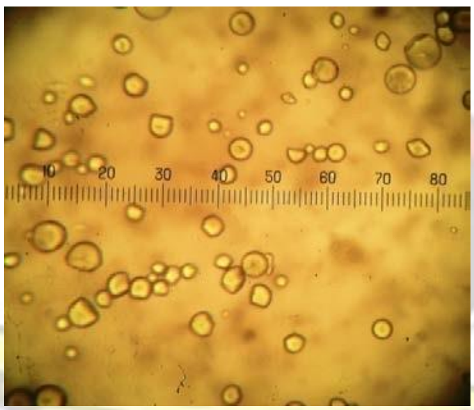
Bankyehemaa 5t/ha P.M



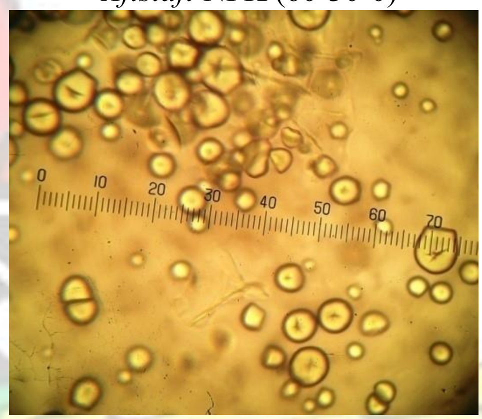
Dokuduade NPK (60-30-0)



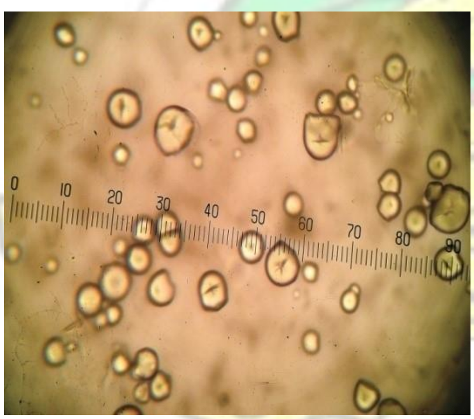
Afisiafi NPK (60-30-0)



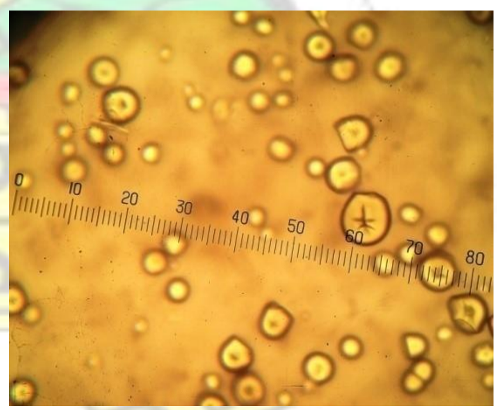
Dokuduade NPK (60-30-60)



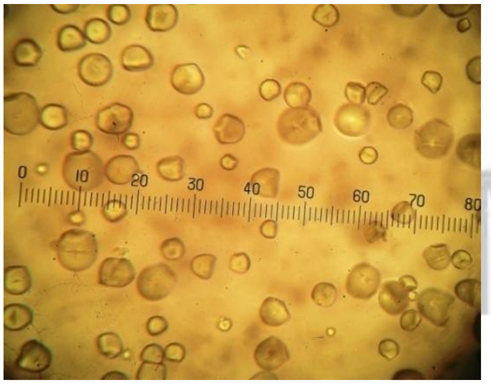
Bankyehemaa NPK (60-30-60)



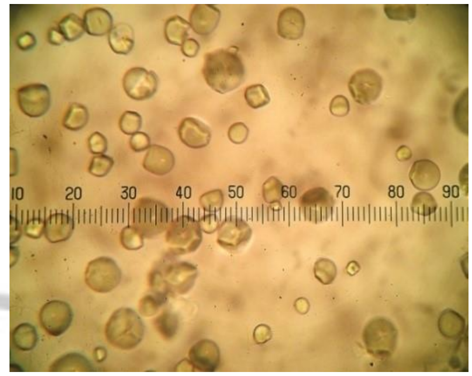
Dokuduade NPK (60-30-90)



Afisiafi NPK (60-30-30)



Afisiafi NPK (60-30-90)

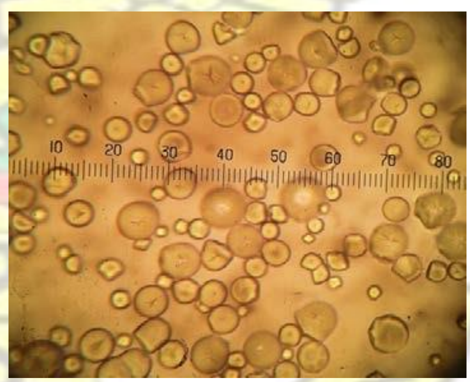


Dokuduade NPK (60-30-30)

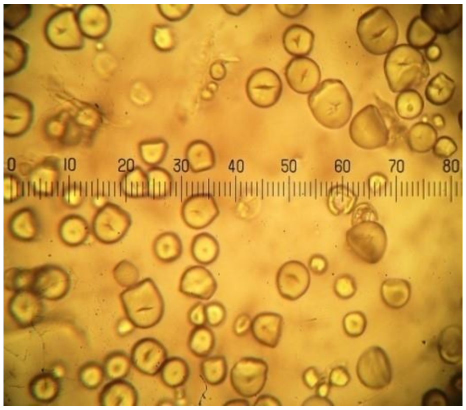
Dokuduade NPK (30-15-15) + 2.5t/ha P.M

Bankyehemaa NPK (60-30-30)

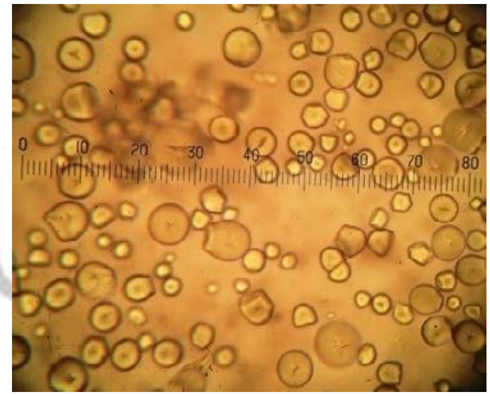
Afisiafi NPK (60-30-60)



Bankyehemaa NPK (60-30-0)



Afisiafi NPK (30-15-15) + 2.5t/ha P.M



Bankyehemaa NPK (30-15-15) + 2.5t/ha P.M

Figure 4.1: Light micrographs of cassava flour starch granules showing shape and size of starch granules of three cassava varieties under different fertilizer protocols.

Table 4.21: Granule size and shape of three Cassava flour starches under different fertilizer protocols as determined by light microscope

Variety	Fertilizer Protocol	Mean Granule size (µm)	Shape description
Afisiafi	Control	14.2^{bcd}	Round/truncated
	2.5t/ha Poultry Manure	14.5^{bcd}	Round/truncated
	5t/ha Poultry manure	14.7^{bcd}	Round/truncated
	NPK (60-30-30)	15.1^{bcd}	Round/truncated
	NPK (60-30-60)	13.0^{d}	Round/truncated
	NPK (60-30-90)	14.2^{bcd}	Round/truncated
	NPK (60-30-0)	13.6^{cd}	Round/truncated
	NPK (30-15-15+2.5t/ha PM.)	15.3^{bcd}	Round/truncated
Overall mean	14.3^{2}		
Dokudaude	Control	14.1^{bcd}	Round/truncated
	2.5t/ha Poultry Manure	13.9^{bcd}	Round/truncated
	5t/ha Poultry manure	16.7^{abc}	Round/truncated
	NPK (60-30-30)	14.7^{bcd}	Round/truncated
	NPK (60-30-60)	14.7^{bcd}	Round/truncated
	NPK (60-30-90)	14.9^{bcd}	Round/truncated

	NPK (60-30-0)	15.9abcd	Round/truncated
	NPK (30-15-15+2.5t/ha PM)	14.1bcd	Round/truncated
Overall mean		14.92	
Bankyehemaa	Control	19.4a	Round/truncated
	2.5t/ha Poultry Manure	16.5abcd	Round/truncated
	5t/ha Poultry manure	15.9abcd	Round/truncated
	NPK (60-30-30)	16.2abcd	Round/truncated
	NPK (60-30-60)	15.3bcd	Round/truncated
	NPK (60-30-90)	16.7abc	Round/truncated
	NPK (60-30-0)	15.9abcd	Round/truncated
	NPK (30-15-15+2.5t/ha P.M	17.4ab	Round/truncated
	Overall mean	16.71	

Mean of three replicates. Mean values in column that do not share a letter are significantly different (p<0.05) from each other, while mean values in column that do not share a number are significantly different (p<0.05) from

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It has been shown from this study that cassava flours have various unequal characteristics that can be utilized in the food industry.

NPK (60-30-90) fertilizer protocol produces cassava flour with the best proximate composition.

Afisiafi, Dokuduade and *Bankyehemaa* cassava varieties were very responsive to potassium fertilizer; however increase amount of K decreases the dry matter content. *Bankyehemaa* variety yield flour with the highest dry matter content.

Afisiafi cassava variety was found to produce flour with the highest yield when the fertilizer protocol NPK (60-30-60) was employed. The value obtained for the flour yield showed that the cassava varieties can be used for industrial flour production.

The physicochemical properties of the flours were significantly affected by the different cassava varieties and different fertilizer protocols. The studies also showed that the different fertilizer protocols had significant impact on the functional properties investigated.

Afisiafi variety gave flour with the highest starch yield under NPK (60-30-30) protocol. Increasing the Level of K in the soil decreases the starch content of cassava flour. NPK (60-30-30) and NPK (60-30-60) fertilizer protocols were the best among the protocols for production of high flour yield and good keeping and baking qualities.

Fertilizer intervention has significant impact on the mineral composition of cassava flour. The use of fertilizer application on soil for cassava cultivation produce flour rich in minerals such as potassium, phosphorus, sodium, calcium and iron and can be formulated into baby foods and as instant flour for convalescence as these categories of people needs high levels of mineral for growth and repair of tissue.

A comparison of the starch granule size of the three cassava varieties revealed that *Bankyehemaa* has larger starch granule than *Afisiafi* and *Dokuduade.* All the cassava varieties exhibited round/truncated starch granule shapes with size range between 13.0 and 19.4µm.

5.2 Recommendation

The following are recommendation established on the findings of this study:

1. It is recommended that *Afisiafi* and *Bankyehemaa* are suitable varieties for flour and starch production due to their high flour and starch yield.

2. Further studies should be done on the three cassava varieties to assess how the fertilizer will impact the cassava at different age of maturity.
3. Cassava flour should be promoted for used as composite flour for the bakery industry.
4. Further studies should be done to assess any possible changes of amylose and amylopectin structure due to different fertilizer protocols.

REFERENCES

Abass, A. B., Onabolu, A. O. and Bokanga, M. (1998). Impact of the high quality cassava flour technology in Nigeria. In: Root crops in the 21st century. Compiled by Akoroda, M.O. & and Ngeve, J. M. Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root.

Addo-Quaye, A. A., Saah, M. K., Tachie-Mensah, C. K. B., Adam, I., Tetteh, J. P., and Rockson-Ako, V. K. (1993). Agricultural Science for Secondary Schools, Ministry of Education, Ghana. Gangaram, H and Sons India.

Adomako,W. J.(2007). Sreening of cassava germplasm for domestric and industrial purpose (unpublish PhD Thesis) Department of Crop Science, University of Cape Coast.

Adeyemi, I. A. and Idowu, M. A. (1990). The evaluation of pregelatinised maize flour in the development of Massai, a baked product. *Nigerian Food Journal* **8**: 63-73.

Adebowale, K. O., Afolabi, T. A., and Lawal, O. S. (2002). Isolation, chemical modification and physicochemical characterization of Bambara groundnut starch and flour. *Food Chemistry* **78**:305–311.

Adebowale, K., Owolabi, B., Olayinka, O. and Lawal, O. (2005). Effect of heat-moisture treatment and annealing on physicochemical properties of red sorghum starch. *African Journal of Biotechnology* **4**: 928-933.

Agbaje, G. O and Akinlosotu, T. A. (2004). Influence of NPK fertilizer on tuber yield of early and late-planted cassava in a forest alfisol of south-western Nigeria. *African Journal of Biotechnol*ogy **3** (10): 547-551.

Agboola, A. A. and Omueti, J. A. (1982). Soil fertility problem and its management in tropical Africa. Paper presented at the International Institute of Tropical Agriculture, Ibadan, Nigeria. p. 25.

Akingbala, J. O., Oyewole, O. B., Uzo-Peters, P. I., Karim, R. O., and Bacuss-Taylor, G. S. H. (2005). Evaluating stored cassava quality in gari production, *Journal of Food, Agriculture and Environment* **3**: 75-80.

Alves, A. A. C. (2002). Cassava Botany and Physiology. In R. J. Hillocks, J. M. Tres, A. C. Bollotti (Eds.). Cassava: Biology, Production and Utilization (67-89) CABI Publication.

Amani, N. G., Buleon, A., Kamenan, A., and Coloma, P. (2004). Variability in starch physicochemical and functional properties of yam (*Dioscorea sp*) cultivated in Ivory Coast. *Journal of Science of Food and Agriculture*, **84**: 2085-2096.

American Association of Cereal Chemist, AACC. (2000). Method 46-11A, in Approved Method of the American Association of Cereal Chemists, 10th edition. AACC, St Paul, MN.

Annor-Frimpong, I. E., Annan-Prah, A. and Wiredu, R. (1996). Cassava as nonconventional filler in communited meat products. *Meat Science* **44**(3):193-202.

Anno-Frimpong, C. (1994). A survey of cassava cultivation practices. In: E Ofori, and S.K Hahn, (Eds). Tropical root crop for developing economy (pp. 216-221). Proceedings of Nineth Symposium of the International Society for Tropical Root Crops, October 20 -26th, 1991. Accra –Ghana.

A.O.A.C, (2000). Official Methods of Analysis.18th edition. Association of Official Analysis Chemists. Arlington. Virginia.

Apea-Bah, F. B, Oduro, I., Ellis, W.O. and Safo-Kantanka, O. (2011). Factor Analysis and aga at harvest effect on the quality of flour from four cassava varieties. *World Journal of Dairy and Food Science* **6**(1):43-54.

Asare, P. A. (2010). Molecular Characterization of cassava germplasm and screening for differences in starch production and resistance to cassva mosaic virus disease. PhD Thesis, department of Crop Science, School of Agriculture, University of Cape Coast, (UCC), Cape Coast, Ghana.

Assanvo, J. B., Agbo, G. N., Behi, Y. Coulin, P. and Farah, Z. (2006). Micoflora of traditional starter made from cassava for "attiéké" production in Dabou (Cóte d'Ivoire). *Food Control* **17**:37-41.

Baah, F. D. (2009). Characterization of water yam (*Dioscorea alata*) for existing and potential food products. PhD Thesis, Kwame Nkrumah University of Science and Technology. (KNUST), Kumasi, Ghana.

Bainbridge, Z., Tomlins, K., Wellings, K. and Westby, A. (1996). Methods for assessing quality characteristics of non-grain starch staple (Part 1 Introduction). Chatham, UK. Natural Resource Institute. pp. 88-95.

Balagopalan C. (2002). Cassava Utilization in food, feed and Industry. Crop Utilization and Biotechnology, Central Tuber Crops Research Institute, Sreekariyam, Trivandrum 695 017, Kerala, India.

Balagopalan, C., Padmaja, G., Nanda, S.K., and Moorthy, S. M. (1988). Cassava in Food, Feed, and Industry. CRC Press Inc: Boca Raton, Florida, USA, p. 205.

Bayu, W., Rethman, N. F. G., Hammes, P. S and Alemu, G. (2006). Effects of Farmyard Manure and Inorganic Fertilizers on Sorghum Growth, Yield and Nitrogen use in a Semi-arid area of Ethiopia. *Journal of Plant Nutrition* **29**(2): 391-407.

Benesi, I. R. M. (2006). Characterisation of Malawian cassava germplasm for diversity, starch extraction and its native and modification properties. PhD Thesis, Department of Plant Science, University of the Free State, South Africa, pp. 74123.

Bhattacharya, M., Zee, S. Y., and Corke, H. (1999). Physicochemical properties related to quality of rice noodles. *Cereal Chemistry* **76**: 861–867.

Boakye, I. K, Ellis, O. W., Oldham, J. H, and Oduro, I. (2001). Characterization of starch from isolated cassava varieties and their possible use for pasta production. *Journal Ghana Science Association,* **3**(2):51-55.

Bokanga, M. (1998). Cassava in Africa: the root of development in the twenty-first century. *Tropical Agriculture* **75**(1-2): 89-92.

Bokanga, M. (1995). Biotechnology and Cassava processing in Africa. *Food Technology* **49** (1): 86-90.

Cadavid, L. F., El-Sharkawy, M. A., Acosta, A. and Sanchez, T. (1998). Long term effects of mulch, fertilization and tillage on cassava grown in sandy soil in northern Columbia. *Field Crops Research* **57**: 45-56.

Cameron K, Wang Y, Moldenhauer A (2007). Comporison of Starch Physicochemical Properties from Medium –Grain Rice cultivars Grown in California and Arkansas. *Starch/Stärke* **59**: 600-608.

Collado, L. S., Mabesa, R. C. and Corke, H. (1999). Genetic variation in the physical properties of sweet potato starch. *Journal of Agriculture and Food Chemistry* **47**: 4195-4201.

Cho Susuna . (1999). Complex carbohydrates in food.

Chen, Z., Schols, H and Voragen, A. (2011). Physicochemical properties of starch obtained from three varieties of Chinese sweetpotatoes. *Journal of Food Science* **68**: 431437.

Colvin, J., Omongo, C. A., Maruthi, M .N., Otim-Nape, G. W., and Thresh, J. M. (2004). Dual begomovirus infection and high Bermsia tabaci populations: Two factor driving the spread of a cassava mosaic virus disease pandemic. *Plant Pathology* **53**: 577-584.

Cousindine, D. M. (1982). Foods and Food production Encyclopiadia. NY: John Wiley Inc.

Daramola, B and Osanyinlusi, S. A. (2006). Investigation on modification of cassava starch using active components of ginger roots (*Zingiber officinale* Roscoe). *African Journal of Biotechnology* **5**(10): 917-920.

Davidson, A. H. and Stanley, G. M. (1975). Human Nutrition and Dietetics, 6th Edn., Longman, London, pp: 208-305.

Debet, M. R and Gidley M. J. (2006). Three classes of starch granule swelling: influence of surface protein and lipids. *Carbohydrate Polymers* **64**:452-465.

Derycke, V., Veraverbeke, W. S, Vandeputte, G. E., De Man, W. and Hoseney, R. C. (2005). Impact of proteins on pasting and cooking properties of non-parboiled and parboiled rice. *Cereal Chemistry* **82**:468–474.

Doku, E. V. (1969). Root Crops in Ghana. *Ghana Journal of Science* **6**: 15-36.

Dorosh, P. (1988). The economics of root and tuber crops in Africa Resources and Crop Management Programme (RCMP). Research Monograph No. 1.International Institute of Tropical Agriculture, Ibadan, p. 23.

Dufour, D., Larsonneur, S., Alarcon, F., Barbet and Chuzel, G. (1996). Improving the breadmaking potential of cassava sour starch. In: Cassava flour and starch: Progress in Research and Development, Eds., Dufour, D., G.M. O'Brien and R. Best, CIAT, Cali, Columbia. pp: 133-142.

Eke-Ejiofor, J. and Owuno, F. (2012). Functional and Pasting Properties of Wheat/ Threeleaved Yam (Dioscorea dumentorum) composite flour blend. *Global Research Journal of Agricultural and Biological Science* Vol. 3(4) pp. 330-335

Ellis, W.O., Oduro, I., Fianko, K., and Otoo, J. A. (2003). Quality of gari from 18 sweetpotato varieties. In: Root Crops; the small processor and development of local food industries for market economy. M.O Akorade (ed.). Proc. 8th symposium of the International Society for Tropical Crops-Africa Branch (ISTRC-AB). pp 146-150.

El-Sharkawy, M. A. (2003). Cassava biology and physiology. *Plant Molecular Biology* **56**: 481-501.

Fennema, O. R (1997). Food Chemistry. 3rd Edition. University of Wisconsin Madison, Marcel Dekker. Inc. New York. pp 157-166.

Food and Agricultural Organization (FAO). (1986). Role of Roots and Tubers and Plantain in Food Security in Sub-Saharan Africa. Report to the Committee on World Food Security 11th Session. 9-16 April 1986. Rome Italy, p 21.

Food and Agriculture Organization (FAO). (2009). Facts and Figures. Rome, Italy. http://www.fao.org/docrep/012/ak341e/ak341e07.htm accessed august 21st 2013.

Fortuna, T., Januszewska, R., Juszczak, L., Keilski, and Palasinski, M. (2000). The influence of starch pore characteristics on pasting behavior. *International Journal of Food Science and Technology* **35**: 285-291.

Freeland-Graves, J. H and Pecham, G. C. (1987). Foundations of Food preparation 5 edition. New York: Macmillan Publishing Company.

Gallant, D. J., Bouchet, B. and Baldwin, P. M. (1997). Microscopy of Starch: Evidence of a new level of granules organization. *Carbohydrate Polymers* **32**:177-191.

Gérard, C., Barron, C., Colonna, P. and Planchot, V. (2001). Amylose determination in genetically modified starches. *Carbohydrate Polymers* **44**:19-27.

Goodhart, L. R. and Shils, M. H (1973). Modern nutrition in Health and Disease. 2nd Edn., McGraw Hill Companies, pp: 145.

Grant, L. A., Dick, J. W., and Shelton, D. R. (1993). Effects of drying temperature, starch damage, sprouting, and additives on spaghetti quality characteristics. *Cereal Chemistry* **70**:676-684.

Gunaratne, A., and Hoover, R. (2002). Effect of heat-moisture treatment on the structure and physicochemical properties of tuber and root starches. *Carbohydrate Polymers* **49**: 425-437.

Hagens P. and Sittibusaya, C (1990). Short-and long-term aspects fertilizer application on cassava in Thailand. In: R.H. Howeler (Ed.). Proc. 8th Symp. Int. Soc. Trop. Root Crops, help in Bangkok, Thailand. Oct 30-Nov 5, 1988. pp. 244-259.

Hao, H. L., Wei, Y. Z., Yang X, Feng Y and Wu, C. Y. (2007). Effect of different nitrogen fertilizer levels on Fe, Mn, Cu and Zn concentrations in shoot and grain quality in rice (*Oryza sativa*). *Rice Science* **1**: 289-284.

Hegenbart, S. (2009).Understanding Starch Functionality. http//www.foodproductdesign.com Virgo Publishers. Accessed on 23rd August, 2012

Henry, G. W., Andres, W. and Collinson, C. (1998). Global cassava end-uses and markets: Current situation and recommendation for further study. A report of an FAO Consultancy by the European Group on Root, Tuber and Plantain. Revision 25/10/98, file:/consultancy/FAO/finrep 11. doc.

Hermansson, A. M and Svegmark, K. (1996). Developments in the understanging of starch functionality. *Trends in Food Science and Technology* **7**:345-353.

Heuberger, C. (2005). Cyanide content of cassava and fermented products with focus on atti´ek´e and atti´ek´e garba. Diss. ETH No. 16247. Dissertation submitted to the Swiss Federal Institute of Technology, Zurich, for the degree of Doctor of Natural Sciences.

Hong, G. P. and Nip, W. K. (1990). Functional properties of precooked taro flour in sorbets. *Food Chemistry* **36**: 261-270.

Howeler, R. H. (2002). Cassava mineral Nutrition and fertilization. CIAT Regional Office in Asia, Department of Agriculture, Chatucchak Bangkok 10900, Thailand Chap 7, p. 116.

http://www.foodmarketexchange.com/datacenter/product/feedstuff/tapioca/detail/dc_pi_ft_tapioca_0203.htm accessed 5th December 2011.

http://www.cgiar.org/iita.

Ihedioha, O, C., Akingbala, J. O. and Oguntimein, G. B. (1995). The effect of holding cassava roots up to four days on quality characteristics of flour milled from the roots. *Journal of food Processing and Preservation* **20**:13-23.

International Institute of Tropical Agriculture (IITA). (2001). Research guide 55. Physiology of Cassava. The Cassava plant p. 2. (http//www.iita.org/info/tmmat/irg553.html).

International Institute of Tropical Agriculture (IITA). (1990). Cassava in Tropical Africa – A reference manual. IITA: Ibadan, Nigeria.

Issaka, R. N., Buri, M. M., Asare D., Senayah J. K, and Essien M. A. (2007). Effects of Cropping system and mineral fertilizer on root yield of cassava. *Agricultural and Food Science Journal Ghana* **6**: 445-458.

Izutsu, T. and Wani, K. (1985). Food texture and taste: a review. *Journal texture Studies* **16** (1):1-28

Jane, J., Kasemsuwan, T. and Chen, J. F. (1996). Phosphorus in Rice and Other starches. *Cereal Foods World* **41**(11): 827-832.

Jane, J. L., Shen, L., Lim, S., Kasemsuwan, T. and Nip, W. K. (1992). Physical and chemical studies of taro starches and flours. *Cereal Chemistry* **69**: 528-535.

Jangchud, K., Yuthana P., and Vichai H. (2003). Physicochemical Properties of Sweet Potato Flour and Starch as affected by Blanching and Processing. *Starch* **55**:258264.

Jansen A. K. (2009) Starch modification. Retrieved January 16, 2012 from http://www.kmc.dk/Productsknowhow/Producttechnology/Modified starch /index.as.htm.

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

Juliano, B. O. (1971). A simplified assey for milled rice amylose. *Cereal Science Today* **16**: 334, 338, 340, 360.

Kang, B. T. and Balasubramanian, V. (1990). Long term fertilizer trials on Alfisols in West Africa. In Transactions of XIV International Soil Science Society (ISSS) Congress, Kyoto, Japan, pp. 350.

Kang, B. T and Okeke. J. E (1991). Potassium and Nitrogen response of two cassava varieties grown in Nigeria. In: Proceedings 6^{th} symposium International society of tropical root crops, Lima, Peru, 21-26 February 1983 pp 231-237.

Katayama, K., Komae, K., Kohyama, K., Kato, T., Seiji, T. and Katsumi K. (2002). New Sweet Potato Line having low gelatinization temperature and altered starch structure. *Starch* **54**: 51-57.

Kaufman, P. B. (1989). Plant: their Biology and Importance. Harper & Row, New York.

Kaur, L., Singh J., and Sigh, N. (2006). Effect of cross-linking on some properties of potato (*Solanum terosum* L.) starches. *Journal of the Science of Food and Agriculture* **86**:1945-1954.

Kayode, O. (1985). Effects of NPK fertilizer on tuber yield, starch contact and dry matter accumulation of white guinea yam (*D. rotundata*) in a forest alfisol of south western Nigeria. *Experimental Agriculture* **21**: 389-393.

Ketiku, A. O. and Oyenuga V. A. (1972). Changes in the carbohydrate Constituents of Cassava root tuber (*Manihot utissima*, Pohl) during growth. *Journal of Food Science and Agriculture* **24**: 275-278.

Khaniki, J. G. H. R., Vaezi, F., Yunesian, M., Nabizadeh, R., and Paseban, G.H.A. (2007) Detection of Baking Soda in Flat Bread by Direct pH Metery and Alkalinity measurement. *Journal of Applied Science* **7** (22): 3584-3587.

Kim, Y. S., Wiesenborn, D. P., Oir, P. H. and Grant, L. A. (1995). Screening potato starch for novel properties using differential scanning calorimetry. *Journal of Food Science* **60**: 1060-1065.

Kulkani, K. D., Noel, G and Kulkani D. N. (1996). Sorghum malt-based weaning food formulations preparation, functional properties and nutritive value.Food and Nutrition Bulletin Vol. 17, No. 2. The United Nations University Press.

Lawton Jr, J. W. (2004). Native starch; uses of. *Encyclopeadia of Grain Science* **1-3**: 195202.

Leach, H. W., Mcowen, D. L., and Schock, T. J (1959). Swelling and Solubility patterns of various starches, structure of starch granules. *Cereal Chemistry* **36**: 53-54.

Leonel, M., Sarmento, S. B. S., and Cereda, M. P. (2003). New starches for the food industry: *Curcuma longa and Curcuma zedoaria*. *Carbohydrate Polymers* **54**:385388.

Liang, X. and King, J. M. (2003). Pasting and crystalline properties differences of commercial and Isolated Rice Starch with added Amino Acids. *Journal of Food Science* 68 Nr.3.

Lombin, L. G., Adepetu, J. A. and Ayotade, K. A. (1991). Organic fertilizer in the Nigerian Agriculture: Present and future F.P.D.D. Abuja, pp. 146-162.

Lii, C., Shao, Y. and Tseng, K. (1995). Gelation mechanism and rheological properties of rice starch. *Cereal Chemistry* **78**(4): 393-399.

Makinde, E. A., Akande, M. O. and Agboola, A. A. (2001a). Effects of Fertilizer Type on Performance of Melon in a Maize-melon Intercrop. ASSET Series, A (2): 151-158.

Makinde, E. A., Agboola, A. A. and Oluwatoyinbo, F. I. (2001b). The effects of organic and inorganic fertilizers on the growth and yield of maize in a maize/melon intercrop. Moor *Journal of Agricultural Research* **2**: 15-20.

Malavotta, E., Graner, E. A., Coury, T., Sober, M.O. C.B., and Pachcco J. A. C. (1955). Studies on the mineral nutrition of cassava *(Manihot utilisima Potil*). *Plant Physiology* **30**:18-82. D.e Okwu & A.N. Awurum: Effect of fertilizer on chemical Composition of Cassava.

Maneepun, S and Sirirojana, V. (1990). Novel uses of modified cassava starch in the Asian food industry. In: Cassava breeding, agronomy and utilization research in Asia: Proceedings of the Third Regional Workshop, Malang Indonesia, October 2227.CIAT, Cali, Colombia. pp. 388-407.

Mat-Hashim, D. G., Moorthy, S. N., Mitchell, J. R., Hill, S. E., Linfoot, K. J and Blanshard, J. M. V. (1992). The effect of low levels of antioxidants on the swelling and solubility of cassava Starch. *Starch/Starke,* **44**:471-475.

Medcalf, D. G and Gilles, K. A. (1965). Wheat Starches 1. Comparison of Physicochemical properties. *Cereal Chemistry* **42**:538-568.

Mestres, C., Matencio, F., Pons, B., Yajid, M., and Fliedel, G. (1996). A rapid method for the determination of amylose content by using differential scanning calorimetry. *Starch/Starke* **48**:2-6.

Ministry of Food and Agriculture (MOFA) (2000). Root tuber, A Newsletter of the Ghana root and tuber Improvement MOFA, IFAD. December 2000, No. 1 pp 2.

Ministry of Food and Agriculture (MOFA) (2005). Agriculture in Ghana, Facts and Figures, PPME, Accra. pp. 26.

Moorthy, S. (2002). Tuber crop starches. Tech Bulletin No.18 CTCRI, Trivandrum.

Moorthy, S. N. (1994).Tuber crop starches. Central Tuber crops Research Institute, Kerala, India. Tech. Bulletin Series 18. pp 40.

Ministry of Food and Agriculture (MOFA) (1997). A case study of cassava development in Ghana: Report submitted to the International Fund for Agricultural Development (IFAD) by the Ministry of Food and Agriculture, Ghana.

Mishra, S., and Rai, T. (2006). Morphology and functional properties of corn, potato and tapioca starches. *Food Hydrocolloids* **20**: 557–566.

Morton, S. (1988). Bread without wheat. *New Scientist* **28**, April, p. 53.

Mweta, E. D, (2009). Physiochemical, functional and structural properties of native Malawian cocoyam and sweet potato Starches. PhD. Thesis submitted to University of Free State Bloemfontein South Africa.

National Agricultural Research Institute (2004). Postharvest Handling Technical Bulletin: Cassava postharvest Care and market preparation. Technical Bulletin No. 21. Ministry of Fisheries, Crops and Livestork. New Guyana Marketing Corporation. pp. 2-3.

Naivikul O. (2004). Rice: Science and technology Kasetsart university Press, Bangkok. (In Thai)

Niba, L. L., Bokanga, M. M., Jackson, F. L., Schlimme, D. S and Li, B. W. (2001). Physiocochemical properties and starch granular characteristics of flour from various *Manihot esculenta* (cassava) genotypes. *Journal of Food Science* **67** (5).

Novelo-Cen l, Betancur-Ancona D. (2005). Chemical and Functional properties of *Phaseolus lunatus* and *Manihot esculata* starch Blends, *Starch/Stärke* **57**:431-441. Cassava

Nowjee, N. C. (2004). Melt processing and foaming of starch. Cambridge: University of Cambridge Press.

Nweke, F. (2004). New Challenges in Cassava Transformation in Nigeria and Ghana, Environment and Production Technology Division, EPTD Discussion Paper No.118, International Food Policy Research Institute Washington, D.C., USA.

Nweke F. I. (1996). Cassava processing in Subsahara Africa. Implementation for expanding cassva Production. *IITA Research* **12**:7-14.

Nweke, F. I., Dixon, A. G .O., Asiedu, R. and Folayan, S. A. (1994a). Collaborative Study of Cassava in Africa. Cassava Variety Needs of Farmers and Potential for Growth in Africa. COSCA Working Paper No. **10**.

Nweke, F. I. (1994b). Cassava processing in sub-Saharan Africa: the implications for expanding cassava production. *Outlook on Agriculture* **23**, 197–205.

Oduro, I., Ellis, W. O., Aryeetey, S. K., Ahenkora, K and Otoo, J. A. (2000). Pasting characteristics of starch from new varieties of sweet potato. *Tropical Science* **40**: 25-28.

Okwu, D. E. (1999). Effects of fertilizer application on oils of ginger rhizome. *Journal of Applied Chemistry and Agricultural Research* **6**:72-75.

Okwu, D. E., and Awurum, A. N. (2001). Effects of fertilizer application of the chemical compostion of cassava tuber and their gari product. *Journal of Applied Chemistry and Agricultural Research* Vol **7**. pp. 112-119 ISSN1117-2894.

Onabolu, A. and Bokanga, M. (1995). Promotion of high quality cassava flour (HQFC) for the food industry in Nigeria. Proc. 6th Symposium of the International Society for Tropical Root Crops-African Branch (ISTRC-AB), pp. 263-269.

Onwueme, I C., and Charles, W. B (1994). Tropical Root and Tuber Crops. Production perspectives and future prospects. FAO Plant Production and Protection Paper, pp 126 FAO, Rome.

Onwueme, I. C. (1978). The Tropical Tuber Crops–Yams, Cassava, Sweet Potatoes and Cocoyam. New York: John Wiley and Sons Ltd, pp 130-132.

Osagie A.U (1992). The Yam in Storage. Postharvest Research Unit, University of Benin, Nigeria.

Osungbaro, T. O. (1990). Effect of differences in varieties and dry milling of maize on the textural characteristic of Ogi (fermented maize porridge) and Agidi (fermented maize meal). *Journal of Science and Food Agriculture* **52**:1-12.

Palm, C. A., Myers, R. J. K and Nandwa, S. M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment In Buresh R. J., Sanchez, D.A., Calhoun F (eds.) Replenishing Soil Fertility in Africa. Soil Science Society of America Madison, Wis., pp. 193-217.

Parkes, E. (2009). Using molecular markers to identify new source of CMD resistance genes for cassava improvement and GSS workshop, CIAT, Cali, Colombia.

Peroni, F. H. G., Rocha, T S. and Franco, C. M. L. (2006). Some structural and physiocochemical characteristics of tuber and root starches. *International Journal of Food Science and Technology* **12** (6):505 -513.

Pérez, E., Schultz, F. S., and Delahaye de E. P. (2005). Characterization of some properties of starches isotaled from *Xanthosoma sagittifolium* (tannia) and *Colocasia esculenta* (taro). *Carbohydrate Polymers*, **60**:139-145.

Plucknett, D. L., Philips, T. P. and Kagho, R. B (1998). A global development strategy for cassava: transforming a traditional tropical root. Paper presented at Asian Cassava Stakeholders' consultation on a global cassava development strategy at Bangkok, Thailand, 23-25 November 1998.

Pomeranz, Y. (1971). Wheat chemistry and Tecchnology, American Association of Cereal Chemists Inc., New York.

Pursegolve, J. W. (1987). Tropical Crops. Dicotyledons. London: London Longman.

Quansah, C., Drechsel, P. and Lefroy, R. B. D. (1997). Peri-urban interface Agricultural Production Systems. Soil Fertility Issues. In: Integrated Nutrient Management of Farmer's Fields-Approaches that work. Gregory, P.J. DFID/NRI/ University of Reading, U. K. Occasional Publications. No.1 199-200.

Ricardo, D., Medina. M., M. Faloci, M., Gonzalez, A. M. and Mroginski, L A. (2007). In vitro Cultured Primary roots derived from stem segments of cassava (Manihot esculenta), Can behave like storage organs. *Annals of Botany* **99**:409- 423.

Rickard, J. E, Asaoka, M. and Blashard, J. M .V (1991) .The physioco-chemical properties of cassava starch. *Tropical Science* **31**, 189-207.

Rickard, J. E. and Coursey, D. G. (1981). Cassava storage pp 1: Storage of fresh cassava roots. *Tropical Science* **23**: 1- 32.

Rogers, D. J. (1963). Some botanical and ethnological considerations of *Manihot esculenta*. *Economy* **19**: 369-376.

Ryu, G. H., Neumann, P. E. and Walker, C. E. (1993). Pasting of wheat flour extrudates containing conventional baking ingredients. *Journal of Food Science* **58** (3): 567573.

Safo-Kantanka, O. (2004). Cassava can replace Cocoa in Ghana I and II. Daily Graphic, May 11-12, 2004 No.149123 and 149124, 9.

Sajilata, M. G., Rekha, S., Kulkarni, P (2006). Resistant Starch - A Review.

Sanni, L., Dixon, B. M, Akanya J, Okoro, C. I., Alaya, Y. Egwuonwu, C. V. (2005). Standards for cassava products and Guilines for Export. IITA, Ibadan, Nigeria 93.

Sarkiyayi, S. and Agar T. M. (2010). Comparative Analysis on the Nutritional and AntiNutritional Contents of the Sweet and Bitter Cassava varieties. *Advance Journal of food Science and Technology* **2**(6): 328-334.

Sharma, A. R. and Mittra, B. N. (1991). Effect of different rates of application of organic and nitrogen fertilizers in a rice-based cropping system. *Journal of Agricultural Science* (Cambridge) **11**7: 313-318.

Shimelis, E., Meaza, M and Rakshit, S. (2006) Physico-chemical properties, Pasting behavior and functional characteristics of flour and starches from improved been (*Phaseolus vulgaris* L.) varieties grown in East Africa. *Electronic Journal of Agricultural Engineering International* **8**: 1-18.

Shittu, T. A., Dixon, A., Awonorin, S. O., Sanni, L. O. and Maziya-Dixon, B. (2008). Bread from composite cassava–wheat flour II: Effect of cassava genotype and nitrogen fertilizer on bread quality. *Food Research International* **41**: 569–578.

Shujun, W., Hongyan, L., Wenyuan, G, Haixia, C., Jiugao, Y., and Peigen. (2006). Characterization of new starches separated from different Chinese yam (*Dioscorea opposite* Thunb). *Food Chemistry* **99**: 30-37.

Singh, N., Singh, J., Kaur, L., Sodhi, N. S., and Gill, B. S. (2003). Morphological, thermal and rheological properties of starches from different botanical sources. *Food Hydrocolloids* **81**: 219-231.

Sittibusaya, C., Narkviroj, C. and Tunmaphirom, D. (1987). Cassava soils research in Thailand. In: Cassava in Asia, its Potential and Research development Needs. Proc. Of a regional Workshop, held in Bangkok, Thailand. June. 5-8, 1984. pp. 277-287.

Tester, R. F., Karkalas, J., and Qi, X. (2004). Starch-composition, fine structure and architecture. *Journal of Cereal Science* **39**:151-165.

Tewe, O. O. and Lutaladio, N. (2004). Cassava for livestock feed sub-Sahara Africa. Rome, Italy: FAO.

Thomas, D. J. and Atwell, W. A. (1998). Starches: Practical guides for the food industry. Eagan Press. St Paul, Minnesota, USA.

Tian, S. J., Rickard, J. E., and Blanshard, J. M. (1991). Physicochemical Properties of Sweet Potato Starch. *Journal of the Science of Food and Agriculture* **57**: 451-491.

Topouzis, D. (2003). Addressing the impact of HIV/AIDS on ministries of agriculture: Focus on eastern and southern Africa. Rome, Italy: A joint FAO/UNAIDS Publication.

Tsou, S. C. S. and Hong T. L (1992). The Nutritional Utilization of Sweet potato. In: Sweet potato technology for the twenty-first Century. Hill, W.A., Bonsi, C. K ., and Loretan, P.A. (Eds.) Tuskegee University : Tuskegee University Press, Tuskegee.

Tukomane, T., Leerapongnun, P., Shabsngob, S. and Varavinit, S. (2007). Preparation and characterization of Annealed-Enzymatically Hydrolyzed Tapioca Starch and the Utilization in Tableting. *Starch/Starke* **59**: 33-45.

Vaclavik, V. A and Christian E. W. (2008). Starches in Food. In: Essentials of Food Science. D. R. Heldman (Ed.) Springerlink, New York, USA, pp 49-67.

Van Hung, P., Maeda, T., and Morita, N. (2006). Waxy and high-amylose wheat starches and flours-characteriztics, functionality and application. *Trends in Food Science and Technology* **17**: 448-456.

Vichukit, V., Phutthacharoen, S., Sarobol, E. and Pedchalanuwat C. (1994). Time of honburi, Thailand. Sept 1-3. Planting and harvesting of cassava. In: Report of a Seminar on Cassava production problems, Utilization and minimizing the cost of production, held in Pattaya, Chonburi, pp. 47-59.

Wheatley, C. C. and Chuzel, G. (1993). Cassava: the nature of tuber and use as a raw material. In R. Macrea, R. K. Robinson, M. J. Sadler (Eds.), Encyclopaedia of Food Science, Food technology and Nutrition. San Diego, C.A Academia Press. pp. 734743.

Wheat Marketing Centre Inc. (2004). Wheat and Flour Testing Methods: A Guide to understanding wheat and flour quality. Portland, Oregon USA.

Wobeto, C., Correa, A. D., de Abreu, C. M. P., dos Santos, C. D., de Abreu, J. R. (2006). Nutrients in the cassava (*Manihot esculenta* Crantz) leaf meal at three ages of plant. Ciencia e technologia de alimentos, *Campinas* **26**:865-9.

Xiong, F., Wang, Z., Gu, Y. J., Chen, C., and Zhou, P.(2008). Effect of nitrogen application time on caryopsis development and grain quality of rice variety Yangdao 6. *Rice Science* **15**:57–62.

Yagodin, B. A. (1984). Agricultural Chemistry. Mir Publishers Moscow pp. 345-350.

Yamazaki, W. T. (1953). An alkaline water retention capacity test for the evaluation of cookies in baking potentialities of soft winter wheat flours. *Cereal Chemistry* **30**: 242-246.

Yuan, Y., Zhang, L., Dai, Y and Yu, J. (2007). Physiochemical properties of starch obtained from *Diocorea nipponica* Makino comparison with other tuber starches. *Journal of Food Engineering* **82**:436-442.

Zaidul, I. S. M., Norulaini, N., Omar, M. O. K., Yamauchi, H., and Noda, T. (2007a). Correlation of the composition of mineral, and RVA pasting properties of various potato starches. *Starch/Stärke* **59**: 269-276.

Zaidul, I. S. M., Yamauchi, H., Takigawa, S., Matsura-Endo, C., Suzuki, T., and Noda, T. (2007b). Correlation between the compositional and pasting properties of various potato starches. *Food Chemistry* **105**: 164-172.

APPENDIX

Appendix 1: Sample of Cassava root used

Appendix 2: Sample of Cassava flour Used

Appendix 3: Apparatus and Samples ready for a day's experiment

Appendix 4: Brabender Viscograph being used to determine pasting properties of flour samples

Appendix 5: Spectrophotometer being used to estimate Amylose content