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Flour from three local varieties of Cassava (*Manihot Esculenta Crantz*): Physico-chemical properties, bread making quality and sensory evaluation

A Minor Field Study in Ghana

Estelle Eriksson

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Estelle Eriksson

Supervisor: Kristine Koch (SLU, Department of Food Science)

Assistant Supervisor: Dr Charles Tortoe (CSIR-Food Research Institute, Accra, Ghana)

Examiner: Annica Andersson (SLU, Department of Food Science

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Abstract

Increasing costs for wheat imports due to higher demand for wheat-based food products in many tropical developing countries such as Ghana has led to an interest in cassava flour as partial substitute for wheat flour in bakery products. The aim of this study was to characterize physico-chemical properties of cassava flour compared to wheat flour and determine its maximum acceptable substitution level in composite wheat/cassava bread and cakes in terms of baking and organoleptical characteristics. Flours from three different local varieties of cassava (*Afisiafi*, *Bankye hemmaa* and *Doku Duade*) were compared. Cassava roots were processed into flour by grating, sun-drying and milling. Quality parameters such as moisture and starch content and acidity as well as functional properties in water such as pasting characteristics, swelling power and water-binding capacity were determined. Breads and cakes including 10, 20 and 30 % cassava flour were baked and evaluated for specific volume, density and hardness. The products were submitted to a semi-trained panel of Ghanaian urban consumers for sensory analysis.

Flour yield from processing of three varieties of cassava roots into flour ranged from 18 to 19.9 %. Swelling power ranged from 10.5 to 12, swelling volume from 8.6 ml to 11 ml, solubility from 11 % to 20.8 % and water-binding capacity from 152 % to 166.9 %, higher values than for wheat flour. This could be explained by a higher starch content in cassava flour that ranged from 87.8 to 89.2% on dry matter basis. Cassava flours were characterized by an early gelatinization (pasting temperature between 70 and 71°C), high peak viscosity, large paste breakdown and low retrogradation tendency compared to wheat flour.

As the substitution level increased in wheat/cassava bread, loaf specific volume decreased and density and hardness increased. Breads baked with 10% and 20% cassava flour were accepted by the sensory panel in terms of appearance, taste and texture and up to 30% was accepted in cakes. These results showed that High Quality Cassava Flour has potential to replace part of the wheat flour in bakery products since there is a wide acceptance among consumers.

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1. Introduction

For the past decades, increasing population, urbanization and changing food habits has led to an increased demand for wheat-based convenient foods in many developing countries. However, as wheat is not grown in countries with tropical climate, they have to rely on expensive wheat imports paid with foreign exchange. With rising wheat prices on the global market, there is an interest to promote utilization of local sources of flour for partial substitution of wheat flour in food products in order to lower the dependency to wheat imports and also to increase livelihoods of local farmers. Cassava is a root crop rich in starch and is widely grown and consumed as a staple food in tropical countries. It requires low inputs of water, fertilizers and labour. In Ghana, cassava is one of the most important crops in terms of production, energy intake, and contribution to Growth Domestic Product. Cassava flour has been examined as a local alternative to wheat flour. The possibility of using starchy tubers instead of wheat flour in foods depends on their chemical and physical properties. Amylose/amylopectin ratio for example influences the flour's behavior in food systems such as viscosity, gelatinization and setback which affect texture of the end product. To be widely accepted by the food industry, cassava flour needs to meet the high quality requirements in terms of physico-chemical characteristics, microbial safety and presence of toxic cyanogenic glucosides. In bakery products, the absence of gluten and the acceptability of the end products among consumers in terms of sensory attributes are important issues to be considered.

The aim of this study was to characterize physico-chemical properties of cassava flour that are important for its functional behaviour in food systems and to analyze relevant quality indicators required by the food industry. The goal was also to determine a maximum inclusion level of cassava flour in composite wheat/cassava bakery products such as bread and cakes without any significant changes in baking capacity and sensory attributes compared to 100% wheat products. Flour from three different varieties were analyzed in terms of physico-chemical properties and baking capacity in order to evaluate how the cassava variety used affected the quality of end products. This study is the basis of a Master's thesis in Food Science at the Swedish University of Agricultural Sciences and was conducted as a Minor Field Study sponsored by the Swedish Development Agency (SIDA) at CSIR Food Research Institute in Accra, Ghana.

2. Literature Review

2.1. The cassava root: traditional processing and utilization in Ghana

Cassava (*Manihot esculenta* Crantz) is a major root crop and an important staple food for over 500 million people in the developing world (Falade, 2010). Cassava is a dicotyledonous perennial plant growing in areas with tropical climate and ranging from 1 to 5 m in height. Although the leaves are edible and often consumed as vegetables, cassava is mainly grown for its starchy tubers, producing 5 to 10 tubers per plant. The crop is traditionally produced in small-scale family farms and mostly processed and consumed at household level. Cassava is a cheap, readily available and reliable source of carbohydrates, particularly in case of food shortage. This drought-tolerant crop has historically played an important role for famine prevention in Eastern and Southern Africa (Nweke, 2005). Compared to cereals such as rice, wheat and maize, cassava requires less labour, water, fertilizer and pesticide input and provides more dietary energy per land unit, being one of the most efficient convertors of solar energy. It is a hardy crop able to grow in dry and nutrient-depleted soils where other crops have failed. In addition, it is grown all year round and can be harvested anytime from 7 up to 18 months after planting (Balagopalan *et al*, 1988).

Africa stands for half of the world's production of cassava. Since 1960, cassava production has tripled to 87 million MT per year in 1999 and the yield has doubled to around 13 tonnes per ha (Nweke, 2005). Ghana is the sixth largest producer of cassava in the world with more than 14 million MT produced per year (FAO STAT 2011), which makes it the most important agricultural commodity as it stands for 22 % of Agricultural Gross Domestic Product (Ministry of Food and Agriculture, 2005). Cassava research was earlier focused on improved yields, better cultivation practices and crop protection but since 1985, it has also encouraged mechanized processing, quality control and development of new products (Adebowale *et al*, 2008). This development has transformed cassava into a commercial cash crop aimed for urban consumers (Nweke, 2005).

Composition of cassava roots

Cassava root is a high energy food with a high water and carbohydrate content. However, an important issue associated with consumption of cassava is the presence of toxic compounds, making it imperative to process the roots before ingestion. *Table 1* gives the average nutritional composition of fresh cassava roots. Cassava roots contain about 60-65% moisture, 30-35 % carbohydrates on fresh weight basis and 80-90 % on dry matter basis (Balagopalan *et al*, 1988). The starch content, representing 80 % of the carbohydrates produced, reaches a peak during the 10^{th} to 11^{th} month after planting. However, peak starch yield differs between cassava varieties, as observed by Apea-Bah *et al* (2011). The composition changes slightly with increasing age as the roots become more fibrous and the starch content declines. Cassava is a poor source of protein as it contains only 1-3% protein on dry matter basis (Montagnac *et al*, 2009) and is low in essential amino acids such as methionine, lysine, tryptophan, phenylalanine and tyrosine (Falade and Akingbala, 2010). A cassava-based diet therefore requires an adequate protein source of good quality to prevent nutritional deficiency symptoms (Balagopalan *et al* 1988).

Table 1. Proximate composition of fresh cassava roots

Component	**Value**
Moisture (g/100 g)	59.4
Carbohydrates (g/100g)	38.1
Protein (g/100 g)	0.7
Fat (g/100 g)	0.2
Crude fiber (g/100 g)	0.6
Ash (g/100 g)	1.0
Calcium (mg/100 g)	50.0
Vitamin C (mg/100 g)	25.2
Energy (kcal/100 g)	157

Balagopalan, 1988

It is well established that cassava is not edible raw due to the presence of toxic compounds. Cassava contains two cyanogenic glucosides, namely linamarin and lotaustralin, present in all parts of the plant with the highest concentration in the root peel. Normal levels of cyanoglucosides range from 31 to 630 ppm calculated as mg HCN/kg of fresh cassava root, although the content varies considerably depending on variety, climate and environmental conditions. Sweet cassava varieties have often lower levels of cyanide than bitter varieties but there is no established correlation between the taste and the toxicity (Falade and Akingbala, 2010). Hydrolyzing enzymes present in the plant, such as linamarase, degrade the cyanoglucosides to hydrogen cyanide HCN as soon as the plant tissue is wounded. If the root is ingested without previous processing, acute poisoning occurs due to the release of HCN in the body. Cyanide affects tissue respiration in mitochondrias, as it is a potent inhibitor of oxidase and other important enzymes in the respiratory chain (Balagopalan *et al* 1988). Chronic exposure of inadequately processed cassava can lead to diseases such as tropical ataxic neuropathy, goiter and cretinism. However, the toxicity can be reduced to safer levels during traditional processing (Falade and Akingbala, 2010).

Importance of processing cassava roots

Although the cultivation of cassava requires low input of labour, post-harvest cassava processing is the most demanding of all root crops as it requires rapid handling and detoxification to make it edible (Root and Tuber Improvement Program, 2004). One of the major issues in the utilization of cassava is the high perishability of the tubers. Deterioration by biochemical changes and microbial infestation starts within 2-3 days after uprooting. Long distances between production areas and processing sites are often a problem leading to considerable post-harvest losses (Balagopalan *et al*, 1988). Since there are no effective commercial storage methods available, it is necessary to process cassava into dry shelf-stable forms by reducing moisture content and thus lowering bulk and transportation costs (Falade and Akingbala 2010).

As cassava contains toxic compounds, it requires special processing procedures that will eliminate or reduce the levels of cyanogenic glucosides, making the product safe for human consumption. Peeling reduces significantly the toxicity. Grating breaks down the internal structure of the root, releasing linamarase that will decrease the cyanoglycoside content by about 95% by hydrolyzing the glucosides into HCN (Falade and Akingbala, 2008). Since HCN is soluble in water, its amount is reduced by traditional detoxification methods such as boiling, soaking or de-watering (Dziedzoave *et al* 2006). Part of the HCN produced will evaporate into the air during drying or roasting since it is volatile. In the case of fermented cassava flours like gari, there is almost a total breakdown of glycosides during fermentation. Consequently, cassava products are safe if processed properly (RTIP, 2004).

Processing also increases the value of cassava by improving palatability and facilitating marketing of more acceptable hygienic quality products. Cassava, often considered as a low value root crop, is transformed into convenient foods to meet the increased demand from the urban population (Falade and Akingbala, 2010). Traditional processing of cassava is a widespread and labour-intensive activity often carried out by women in small-scale processing units. The different units operations like peeling, grating, drying, sifting, roasting and fermentation are time-consuming since they are often carried out by hand. Nevertheless, the introduction of motorized cassava processing equipment over the past three decades has considerably reduced the drudgery and created a higher processing rate. Mechanical graters, cassava chippers, screw presses, sieving machines, mills and mechanical dryers are now fairly established in the cassava processing industry in Ghana. However, small-scale cassava processors often lack capital to invest in equipment and keep the activity profitable (Ministry of Food and Agriculture, 2005).

Traditional uses of cassava in Ghana

It is estimated that cassava accounts for 30 % of the daily calory intake in Ghana and is grown by nearly every farming family (Odedina and Adebayo, 2012). About 30 % of the cassava produced is consumed by the producers themselves. The rest is sold at the market or processed into various types of fermented flours, such as gari and agbelima, which are the most widely used cassava products. (Ministry of Food and Agriculture, 2005). Cassava is also consumed boiled or roasted, along with spices and vegetables. Fufu is prepared by pounding the fresh, peeled and boiled cassava roots into a thick and smooth paste (Apea-Bah *et al* , 2011). Food Research Institute of the Council for Scientific and Industrial Research and other private entrepreneurs have started to produce new convenient foods made from cassava such as fufu flours to promote consumption of cassava and add value to the root. The products are popular among Ghanaian consumers but their price is not yet competitive (Ministry of Food and Agriculture, 2005).

High value and shelf stable cassava products that may offer export opportunities and possibility to earn foreign exchange include cassava starch and High Quality Cassava Flour. Starch extracted from cassava roots is used as an important raw material in the food industry but also in the non food industry for textile, paint, cement, detergents, plywood, paper and for pharmaceutical uses. Some characteristics of cassava starch include high paste viscosity, high paste clarity and high freeze-thaw stability, which are valuable for many industries (Odedina, Adebayo, 2012).

2.2. High Quality Cassava Flour

Intended use of HQCF

The production process of High Quality Cassava Flour (HQCF) was initially developed at the International Institute for Tropical Agriculture (IITA) in Nigeria as an alternative to imported wheat flour for the food and non-food industry and the technology is now used in some cassava-growing nations (Falade and Akingbala, 2008). HQCF is defined as an un-fermented, white, smooth and odourless cassava flour. It is rapidly processed from healthy cassava roots harvested 10-12 months after planting. It is intended to be used as raw material in the food and beverage industry for the manufacture of pastries, biscuits, noodles, baby foods, alcoholic drinks and as binding and thickening agent in soups and stews. It is also suitable in the manufacture of gum, glues, paperboard adhesives, textiles, plywood, paper, pharmaceutical drugs and glucose syrup. However, the most important potential use is in composite with wheat flour in high-grade foods such as bread. HQCF production differs from production of traditional fermented cassava flours such as gari and agbelima by the absence of extensive fermentation that gives a low pH and a sour taste, unsuitable for inclusion in industrial products (Dziedzoave *et al*, 2006).

Cassava flour production and quality requirements

The processing of cassava roots into High Quality Cassava Flour is described in *Figure 1*. Healthy cassava roots with no bruises and cracking should be harvested 10-12 months after planting and processed within 24 hours (Dziedzoave *et al*, 2003). The indigestible outer layers of the root are removed, usually by hand with a sharp stainless steel knife. However, mechanical peelers are used by large-scale processors (UNIFEM 1993). The peeled cassava roots are washed with water of potable quality with a sponge to remove impurities. Grating is generally carried out by a motorized cassava grater that disintegrates cassava tissue, which facilitates later steps such as pressing and drying due to an increased surface area. De-watering or pressing is the removal of internal liquid from the roots by means of a screw press and is important to reduce toxicity. The cassava mash is packed into a clean jute sack that allows the excess water to pour out until it is crumbly. Off colour and odour from fermentation is avoided by keeping the pressing time short (less than one hour). Disintegration reduces the particle size of the cassava crumbles (Dziedzoave *et al*, 2003). Drying can be carried out by a hot air mechanical dryer or a solar dryer. Drying involves the transfer of moisture from the product to the surrounding air and is affected by the air flow, the relative humidity of the air and the moisture content of the product. To speed up the drying process, heating the air is often necessary in humid areas with a relative humidity of 75% or more, as the relative humidity of air decreases when its temperature increases (UNIFEM 1993). A loading rate of 1.0 kg/m^2 is recommended for a drying within 6-7 hours and drying temperatures should not exceed 60°C. The dried cassava mash is milled into flour by a hammer or disc-attrition mill. The flour is sieved by means of a motorized flour sifter fitted with a 250 µm screen in order to obtain smooth flour with a uniform particle size. Finally, the flour is packaged in polypropylene sacks to avoid moisture uptake of the flour during storage (Dziedzoave *et al*, 2003).

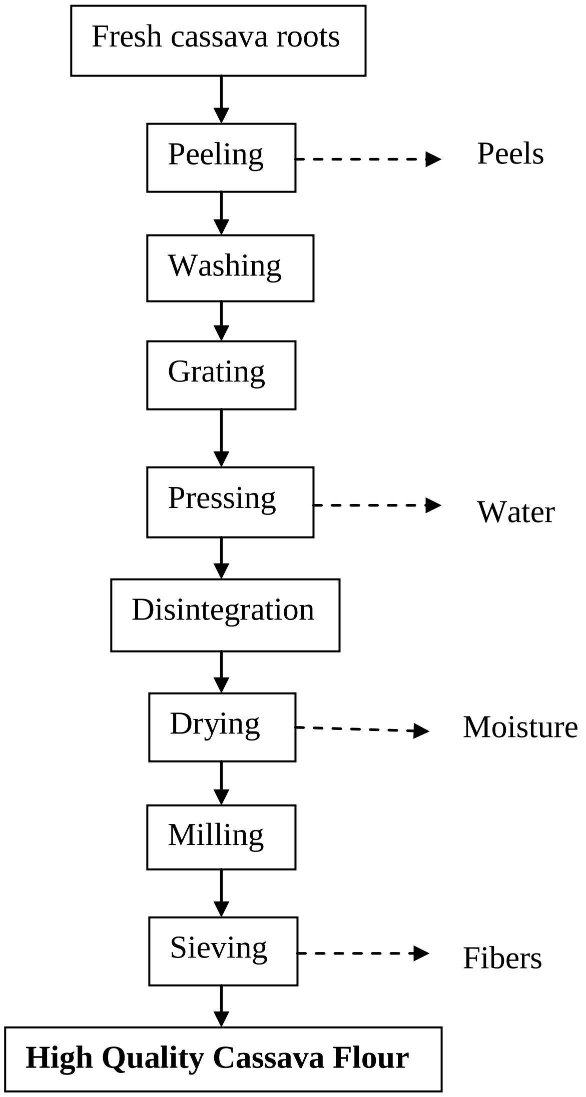

Figure 1. Flow chart for production of High Quality Cassava Flour

Some objective quality parameters of High Quality Cassava Flour required by the industry for food uses are presented in *Table 2*.

Table 2. Physical and chemical quality characteristics and requirements of HQCF for food uses

Characteristics	Quality levels
Moisture content	8-10 %
Starch content	65-70 %
pH	6-7
Total titratable acidity (as lactic)	< 0.25%
Particle size	250-500 µm
Colour	L* > 99
	a* < 8
	b* < (-4)
Total cyanogens (CNP)	< 10 mg/kg HCN eq
Pasting temperature	< 74 °C
Cook Paste Viscosity	>750 BU

Dziedzoave *et al*. 2003, Dziedzoave *et al*. 2006

2.3. Starch in foods

Composition of starch

The major component of High Quality Cassava Flour is starch. Starch is composed of two polysaccharides and plays an important role for the storage of energy in most higher plants, especially tubers. Amylose, the minor component, has a linear structure of α-D-glucopyranose units joined by α (1-4) D-glucosidic linkages, while amylopectin, with a higher molecular weight, has a branched structure due to the presence of α (1-6) linkages. The structural differences of the two polymers give them different properties in aqueous solutions. Amylopectin is more stable due to its branched nature and amylose molecules have a tendency to precipitate spontaneously due to the formation of hydrogen bonds between aligned molecules (Balagopalan *et al*, 1988).

Functional properties of starch

The behaviour of starch in foods is often studied in excess water systems. Swelling power and solubility are important properties that vary according to botanical origin of starches and are often regarded as the main criterion of starch quality for bakers and manufacturers (Dufour, 1996). Swelling power, expressed as the weight of sediment per gram of starch, is defined as the maximum increase in volume and weight that the starch undergoes when heating in excess water. Solubility is the percentage of starch that is dissolved after heating. There is thus a direct relationship between swelling power and solubility. The swelling volume is the volume of the undissolved sediment obtained after centrifugation of the sample (Balagopalan *et al*, 1988).

Starch gelatinization

In the preparation of cereal-based foods, the starch is at some point heated in the presence of water. The unique character of many foods results from the changes that starch undergoes during heating and subsequent cooling; it is therefore important to understand what happens to starch under relevant cooking conditions (Delcour and Hoseney, 2010). When an aqueous solution of starch is heated, water molecules enter the native starch granules and disrupt the hydrogen bonding between the starch polymers. The granules absorb a large amount of water and swell. When a critical temperature is reached, the irreversible process known as gelatinization occurs. It is characterized by a loss of birefringence of the starch granules and is accompanied by a sharp rise in viscosity. Viscosity, an important property of starch solutions, can be recorded using a Brabender viscoamylograph. During the pasting test, the mixture is gradually heated to 95°C under constant stirring, temperature is maintained for a fixed hold period and cooled to 50 °C. The gelatinization or pasting temperature is characteristic for a particular type of starch and indicates the minimum temperature required to cook a sample of starch and consequently also energy costs. It is often expressed as a range of temperature of around 10°C, showing that gelatinization is a granule-by-granule event. Above this temperature, during the hold period, starch granules rupture and amylose molecules leach out and align in the direction of shearing, leading to a decrease in viscosity often referred as shear thinning (Adebowale *et al,* 2008). During subsequent cooling, the starch paste undergoes retrogradation, which corresponds to an increased rigidity in the starch gel when starch molecules re-associate by hydrogen bonding. Retrogadation is strongly influenced by the amylose content of the starch. The Brabender curve gives five points of interest. Peak viscosity is the highest viscosity the starch paste can reach. Viscosity at 95°C gives an idea of the ease of cooking of starch. Viscosity during hold period at 95°C reflects the ability of the paste to resist breakdown on shearing. Setback is the viscosity of cooked paste during cooling. Final viscosity indicates the stability of the cooked paste after a definite period at 50°C (Balagopalan *et al* 1988).

2.4. Baking: quality and sensory aspects

Starch-in-water solutions used to understand properties of a particular starch or flour are quite different from the concentrated food systems found for example in baked products (Delcour and Hoseney, 2010). To evaluate the breadmaking quality of wheat/cassava composite flour, baking tests is the most reliable method.

Baking procedure

The essential ingredients in bread making are flour, yeast, salt and water. Flour for bread making is usually produced from hard wheat that has a high protein content since the amount and the quality of protein in flour are important for its bread-making capacity and loaf volume. It has been found impossible to bake a loaf of good quality with a flour that contains a low level of protein, e.g. ≤ 8 %. The wheat storage proteins glutenin and gliadin together form gluten during mixing of wheat flour with water (Delcour and Hoseney, 2010). Gluten plays a major role for the rheological properties of the dough, forming a strong, elastic and cohesive network that retains gas during fermentation and eventually produces a light and leavened bread. During baking in oven, a number of physical, chemical and biological changes take place, such as evaporation of water, formation of porous structure, volume expansion, protein denaturation and crust formation. Starch also undergoes swelling and gelatinization at baking temperatures, thus contributing to bread expansion (Ninjin *et al*, 2011).

Quality and sensory evaluation of bread

Loaf volume is widely used as a measure of bread-making capacity. The specific volume of a loaf of bread is the ratio between its volume and weight and has been adopted as a reliable measure of loaf size (Shittu *et al*, 2007). Some general quality parameters of white wheat bread include a white crumb colour, high volume, a smooth and crusty surface, small pores in the crumb, soft and elastic texture and a good taste. However, what makes a bread of good quality is highly individual and can vary according to culture, tradition and food habits. It is therefore important to evaluate preference and acceptability among the target consumers when introducing a new product on the market since the sensory perception is essential to the food choice behaviour. Sensory evaluation is a useful tool for food and beverage companies in assessing acceptability of their products. It is defined as "a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing" (Stone and Sidel, 2004). Three types of sensory testing are commonly used, discrimination, descriptive and affective tests, the primary purpose of an affective (or hedonic) test being to quantify the degree of liking of a product. Participants to the sensory panel should be representative of the consuming population or target group. As untrained panelists, they should be regular users of the product in order to be familiar with its sensory attributes. The 9-point scale, also known as a degree-of-liking scale, is the most common hedonic scale as it is very simple to use and easy to implement. It is based on equal interval spacing which gives the responses numerical values that can be used for statistical analysis. In a hedonic test, panelists are not asked to give specific information about product sensory attributes since untrained subjects often exhibit more individual differences in their interpretation than trained panelists. The aim here is to predict consumer response and readiness to buy the product (Lawless and Heymann, 1999). Although there are important links between sensory evaluation and marketing research, they should not substitute one another (Stone and Sidel, 2004).

3. Materials and Methods

3.1. Processing of cassava into flour

Three different local cassava varieties, namely *Afisiafi*, *Bankye hemmaa* and *Doku duade*, were processed with identical procedure at CSIR FRI Roots and Tubers Product Development Unit at Pokuasi north of Accra, Ghana. The roots were processed one day after harvest. All the processing machines used have been manufactured at CSIR Food Research Institute, Accra. The roots were peeled by hand, washed with tap water, grated with a motorized cassava grater, pressed in a sack using a manual screw press. The cassava mash was disintegrated in the cassava grater and dried in a solar dryer where the temperature varied between 35 and 48 °C. It was then milled into flour using a disc-attrition mill. A motorized flour sifter with a 250 µm screen was used to remove fibers and bigger particles in order to obtain fine flour with a uniform particle size.

3.2. Physico-chemical analysis of flours

Preparation of samples

The flour blends which were analyzed were mixed and coded according to the proportions presented in *Table 3*.

Table 3. Formulation of wheat/cassava flour blends

Sample	Afisiafi flour (%)	Bankye hemmaa flour (%)	Doku Duade flour (%)	Hard wheat flour (%)
A 10%	10			90
A 20%	20			80
A 30%	30			70
A 100%	100			
B 10%		10		90
B 20%		20		80
B 30%		30		70
B 100%		100		
D 10%			10	90
D 20%			20	80
D 30%			30	70
D 100%			100	
W (control)				100

Moisture content

Moisture content was determined in triplicate on Hard wheat flour (W), Afisiafi flour (A 100%), Bankye hemma flour (B100%) and Doku Duade flour (D 100%), according to the method of Bainbridge *et al* (1996). Approximately 3 g of sample of flour was placed in pre-weighed moisture dishes. The flour samples were dried in an oven at 105°C for 4 hours. The samples were placed in a desiccator for 30 min to cool before weighing. The moisture was calculated by the formula

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

W_1 is the weight of the dish, W_2 the weight of the dish + the weight of the sample before drying and W_3 the weight of the dish + the weight of the sample after drying.

Water activity

Water activity was measured using standard methods in triplicates with a Rotronic Hygrolab 2 (Erotronic ag Ltd. USA).

pH

10.0 g of flour sample was weighed into a 250 ml beaker. 90 ml of distilled water was added and mixed well. The mixture was left for 1 hour at room temperature. The pH was measured in triplicate using a pH meter.

Total Titratable acidity

The samples for pH measurement were used for determination of total titratable acidity. 4-5 drops of phenolphthalein indicator were added to the solution. Titration was carried out by adding 0.1 M NaOH until end point identified by a color change to pink. The volume of NaOH added was multiplied by 0.09 to obtain the % titratable acidity as lactic acid.

Starch content of flours

The starch content was determined by the method of Åman *et al* (1994) with some modifications concerning the glucose oxidase reaction and final reagent volume. Approximately 40 mg of flour sample was dissolved in 15 ml of 80% ethanol, placed in a boiling water bath for 30 min, centrifuged for 10 min (900 g) and the pellet was washed twice with 80% ethanol before decanting the solvent by inverting tubes on tissue paper. This first step was carried out to eliminate low molecular weight carbohydrates that could interfere with the subsequent starch analysis. 25 ml acetate buffer (0.1 M, pH 5.0) and 50 µl termamyl (α-amylase) from Megazyme was added to the sample, the tubes were placed for 30 min in a boiling water bath and shaked three times during incubation. After cooling to 40°C, 100 µl amyloglucosidase (diluted 1:9 with 0.1 M acetate buffer) was added in order degrade the starch into glucose units and the samples were put in 60 °C shaking water bath over night. After centrifuging (10 min, 900 g), 40 µl of supernatant was diluted with distilled water to 1:25 and 3 ml GOPOD from Merck (Bergman & Beving Lab) was added. The sample was placed in 50 °C water bath for 20 min and absorbance was read at 510 nm in Shimadzu UV Spectrophotometer. Glucose concentration in the flour samples were determined from a standard curve with solutions stretching from 0.025 to 0.100 mg/ml. Starch content was calculated using following formula:

$$\%\ starch\ (dry\ matter) = \frac{[glucose](\frac{mg}{ml}) \times 25.15 \times 0.9 \times 25}{sample\ weight\ (mg, DM)}$$

Amylose content of flours

100 µl of a sample solution composed of approximately 50 mg of flour and 6 ml UDMSO (0.6 M urea in 90% Dimethyl sulfoxide) was mixed with 900 µl absolute ethanol. The samples were centrifuged (2000 g, 15 min), washed with 2 ml 95 % ethanol and centrifuged again. After decanting the solvent, 100 µl UDMSO was added to the pellet and placed 15 min in a boiling water bath for complete dissolution. 5 ml 0.5 % trichloroacetic acid (TCA) and 50 µl iodine solution (1.27g I_2 and 3.00 g KI per litre) was added and mixed immediately. After

30 min at room temperature, absorbance was read at 620 nm with water as reference. The amylose content of the flour was calculated using a standard curve.

Colour

The colour of the cassava flours and the wheat flour was measured with a Minolta CR-310 (Minolta camera Co. Ltd, Osaka, Japan) tristimulus colorimeter, recording L, a* and b* values. L represented lightness (with 0= darkness/ blackness to 100= perfect/brightness); a* corresponds to the extent of green colour (in the range from negative= green to positive = redness); b* represents blue in the range from negative=blue to positive=yellow.

Swelling power, swelling volume, solubility

The swelling power, swelling volume and solubility were determined based on a modification of the method of Leach *et al*., (1959) on all the blends. 1.0 g of sample was transferred into a weighed graduated 50 ml centrifuge tube. Distilled water was added to give a total volume of 40ml. The sample in the tube was stirred gently by hand and then heated at 85ºC in a water bath (Grant instruments Ltd, Cambridgeshire, UK) for 30 min with constant shaking. After cooling to room temperature, the samples were centrifuged for 15 minutes at 2200 rpm (REMI R23). The supernatant was transferred into a can, dried in a hot air oven (BS Gallenkamp, England) and the dry residue was weighed. The sediment paste (pellet) was weighed. The swelling volume was obtained by directly reading the volume of the sediment in the tube. The solubility and swelling power was calculated by the formulas:

$$Swelling\ power = \frac{W_{pellet}}{W_{sample\ dry\ basis} - W_{dried\ residue}}$$

$$Solubility\ (\%) = \frac{W_{dried\ residue}}{W_{sample\ dry\ basis}} \times 100$$

W_{pellet} is the weight of the sediment paste after centrifugation, $W_{sample\ dry\ basis}$ is the weight of the initial sample on dry basis, $W_{dried\ residue}$ is the weight of the residue of supernatant after drying.

Water-binding capacity

The Water binding capacity was determined in triplicate on all the flour blends according to the method of Yamazaki (1953) as modified by Medcalf and Gilles (1965). 2.0 g of sample was dissolved in 40 ml of water in a centrifuge tube. The suspension was agitated for 1h at room temperature on a shaker (Grant instruments) and centrifuged for 10 min at 2200 rpm. The free water was decanted from the pellet and drained for 10minutes. The pellet was weighed and water-binding capacity of the sample was calculated by the formula:

$$WBC = \frac{W_{bound\,water}}{W_{sample}} \times 100$$

$W_{bound\ water}$ is the weight of the pellet after centrifugation – weight of the initial sample and W_{sample} is the weight if the initial sample.

Pasting properties

To analyze pasting properties of cassava flours upon heating and subsequent cooling, a Rapid Visco Analyzer (RVA) from Newport Scientific (Warriewood, Australia) was used. RVA General Pasting Method (STD1) was applied. Total running time was 13 min and the viscosity values were recorded every 4 seconds by Thermocline Software as the temperature increased from 50 °C to 95 °C before cooling to 50 °C again. Rotation speed was set to 960 rpm the first 10 seconds and to 160 rpm until the end. 3.00 g of flour and 25.0 ml of distilled water were placed into a canister. A paddle was inserted and shaken through the sample before the canister was inserted into the RVA.

3.3. Bread-making capacity of composite wheat/cassava flour and sensory evaluation of breads and cakes

Baking procedure

Bread loaves were baked with the ingredients listed in *Table 4*, the proportions expressed as the percentage of flour used. The ingredients were purchased at the local market. Part of the hard wheat flour was substituted by flour from the three analyzed cassava varieties (*Afisiafi, Bankye hemmaa* and *Doku Duade*), at replacement levels of 10, 20 and 30% (*Table 3*). The proportions of the remaining ingredients were not changed. Bread baked with 100% wheat flour was used as control. All ten flour samples were baked in duplicate. The dough was kneaded by hand for 20 min, molded into loaves and proofed for 3 hours at room temperature. The loaves were baked in an oven at 180°C for 25 minutes.

Table 4. Ingredients used for baking of bread

Ingredients	Baker's percentage (%)
Flour	100
Water	43.6
Margarine	16.6
Sugar	8.3
Concentrated milk	2.3
Salt	0.9
Dried yeast	0.6
Vanilla flavour	0.4
Nutmeg	0.2

Specific volume and density of bread loaf

The bread loaves were allowed to cool to room temperature and the loaf weight (W) was measured on a digital scale. Loaf volume (VL) was determined by a modification of the rapeseed replacement method according to the procedure of AACC (2000), using millet instead of rapeseeds. The bread loaf was put in a basin of known volume (VB). The container was filled to the top with millet, the loaf was removed and the volume of the millet (VM) was measured with a measuring cylinder. Loaf volume (VL) was then determined according to the following formula:

$$VL\ (cm^3) = VB - VM$$

Specific volume (SV) was calculated as follows:

$$SV\ (cm^3/g) = \frac{VL}{W}$$

And the density (DL):

$$DL\ (g/cm^3) = \frac{W}{VL}$$

Texture analysis of bread

18 g of dough made from each flour sample was weighed in aluminum moulds of 30 mm in diameter. 5 bread samples per flour blend were baked and allowed to cool to room temperature. The hardness of the bread samples, i.e the peak force required to compress it, was measured with a Texture Analyser Stable Micro Systems Ltd (Surrey, UK), using a 75 mm Compression platen probe. The probe was set to compress the samples from a height of 45 mm down to 23 mm, corresponding to half of the average bread sample height.

Sensory evaluation

Bread loaves were allowed to cool for 1 hour, cut into slices of uniform thickness and placed on plates coded with random 3-digit codes. A sensory panel consisting of 20 semi-trained staff members and graduate students at CSIR Food Research Institute and familiar with sensory attributes of local bread agreed to evaluate the products. A 9-point hedonic scale was used to rate the breads for appearance, taste, texture and overall acceptability (Appendix 1). A score of 1 represented “dislike extremely” and a score of 9 represented “like extremely”. Four bread samples were evaluated simultaneously and served randomly and individually to the panelists along with water and neutral cream crackers. The sensory evaluation was performed in a ventilated room with conventional lightning and equipped with individual booths. Queen cakes made with 10, 20 and 30 % cassava flour of the three cassava varieties were baked according to the recipe in Appendix 2 and were evaluated for the same sensory attributes.

3.4. Statistical analysis

The data obtained were analyzed using SPSS 16.0. One-Way Analysis of Variance (ANOVA) and Duncan test with a level of significance of p=0.05 were performed to evaluate differences in physico-chemical characteristics of cassava flours, in baking properties and in sensory attributes of bread samples baked with increasing amount of flour from different cassava varieties.

4. Results and Discussion

4.1. Processing of cassava roots into High Quality Cassava Flour

The results from the production process of cassava roots into High Quality Cassava Flour are given in *Table 5* for the three cassava varieties *Afisiafi* (A), *Bankye hemmaa* (B) and *Doku Duade* (D) that were used. Flour yield and percentage of peels, water and fibers removed during processing are presented. The peels were removed by hand, the water content reduced by pressing and drying and the fibers were sorted out by the flour sifter.

Table 5. Flour yield and proportion of peels, water and fibers removed during process, as percentage of fresh cassava weight

Cassava variety	Flour yield (%)	Peels (%)	Water (%)	Fibers (%)
Afisiafi	18	38	41.1	2.5
Bankye hemmaa	18.2	44.8	35.2	2.4
Doku Duade	19.9	34.5	41.2	4

The flour yield ranged from 18 to 19.9 %. *Doku Duade* had the highest and *Bankye hemma* the lowest yield. Since the recovery rate should range between 13 and 19 % with the aim set at 18 % according to Dziedzoave *et al* (2003), the results are acceptable. The starch and fiber content in cassava roots vary over time and therefore the flour yield depends on the maturity of the cassava plant at the time of harvest, initial root moisture content and also on the variety used for processing into flour (Dziedzoave *et al*, 2003). Although cassava can be harvested anytime during the year and does not have a critical planting date, enough moisture is necessary for the rooting. In West Africa, planting is therefore usually carried out from the beginning of the rainy season (February–March) to the end of the rainy season (October-November) (Nweke, 2005). Cassava roots are usually harvested 10-12 months after planting, from December to June. However optimal age for harvest depends on the cassava variety used since flour yield reaches a peak at different times after planting. Apea-Bah *et al* (2011) found that Afisiafi had its peak flour yield (23%) 13 months after planting. In September-November, at the time of this study, cassava was scarce and expensive (Baidoo E., personal communication). Apea-Bah *et al* (2011) reported that the age at harvest also significantly affected the moisture content of cassava flour. Defloor *et al* (1994) found in a study about bread made with cassava flour, defatted soya flour and glyceryl monostearate (80:20:3, w/w) that the age of cassava at harvest affected breadmaking potential of cassava flour more than the variety or genotype used to produce the flour and that flour from crops harvested 12 months after planting gave a bread with the best crumb characteristics. The observed differences in breadmaking potential were attributed to differences in gelatinization temperatures (Defloor *et al*, 1995)

Since cyanide content in cassava roots and flour is an important food safety issue, studies have been done on the effect of processing method on the cyanide concentration of flour. Cardoso *et al* (2005) reported that when crushing and sun drying is used such as in the process into unfermented HQCF, the maximum cyanide level in the fresh cassava roots should range between 125 and 267 mg HCN equivalents/kg fresh roots (ppm) in order to obtain flour with less than 10 ppm, the safety level set by WHO, since the retention level of cyanide during process is 1.5-3.2 %. Sakyi-Dawson *et al* (2006) reported that both variety and processing methods affected the chemical composition, cyanide levels and viscosity of the flour, grated cassava giving flour with the lowest cyanide level. Almazan (1990) also found that cyanide concentration in wheat/cassava bread depended on the cassava variety used and on the percentage substituted. Sweet cassava varieties with low cyanide content are the most common in Ghana (Nweke, 2005). In addition, the dilution with wheat flour in the composite flour and the high temperature required for baking bread contribute to reduction of cyanide to safe levels.

4.2. Physico-chemical properties of High Quality Cassava Flour

Results from the determination of moisture content, water activity, pH and total titratable acidity are given in *Table 6*.

Table 6. Moisture content, water activity, pH and total titratable acidity of flour from three cassava varieties and wheat flour

Cassava variety	Moisture content (%)	Water activity	pH	Total titratable acidity (%)
Afisiafi	10.75	0.61	6.85	0.37
Bankye hemmaa	11.06	0.61	7.05	0.36
Doku Duade	10.30	0.61	6.73	0.41
Control (Hard wheat flour)	11.81	0.68	6.42	0.45

Cassava flours had lower moisture content and water activity than the hard wheat flour used as control, which can be attributed to different storage conditions and packaging materials. Even though the moisture content in cassava flours were higher than the recommended level (8-10 %), the low water activity may prevent growth of microorganisms and fermentation. Since the flours were produced and stored in identical conditions, differences in flour moisture content may be attributed to varietal differences, which requires analysis of moisture content of fresh cassava roots of the same age at harvest to be confirmed. Environmental conditions such as rainfall may also affect quality of the final baking product. Eggleston

(1993) reported that amylase activity was highly dependent on the moisture content of freshly harvested cassava tubers. A high amylase activity affects bread loaf characteristics such as reduced specific volume and sticky crumb.

The pH was higher in cassava flour than in the control and ranged between 6.73 and 7.05, which was acceptable according to the quality requirements. The pH is a good quality indicator for cassava flour since flour with a pH of 4 or less will have a characteristic sour aroma and taste due to fermentation, which is not desirable for use in bakery products (Apea Bah *et al* 2011).

The results from the colour determination given in *Table 7* indicate that cassava flours had a lighter colour than the control (91.43-95.43 compared to 89.71) and wheat flour was slightly more yellowish (9.75 compared to 4.96-5.16).

Table 7. Colour determination of flour from three cassava varieties

Cassava variety	**L**	**a**	**b**
Afisiafi	93.97	-0.22	5.15
Bankye hemmaa	91.85	-0.31	5.16
Doku Duade	95.43	-0.25	4.96
Control (Hard wheat flour)	89.71	-0.85	9.75

Table 8 shows the results of the analysis of starch and amylase content, from which amylose/amylopectin ratio could be calculated. Starch content of cassava flour on dry matter basis ranged from 87.8 to 89.2 %, which was higher than the starch content of the wheat flour used as control (81%). These results are consistent with those found by Moorthy *et al.* (1996) who reported 79 and 86 % on fresh weight basis, depending on the variety. The values for amylose content in cassava starch ranged from 9.3 to 11.9 % and were lower than those found by Eggleston (1993) and Defloor *et al* (1998), 12.05-13.88 % and 17.9-23.6 % respectively. Balagopalan (1988) has reviewed the properties of cassava flour and starch and reported that normal amylose values for cassava starch are 16 to 18 %.

Table 8. Starch and amylose content

Cassava variety	**Starch content (% of flour, dry matter)**	**Amylose content (% of flour, dry matter)**	**Amylose/amylopectin ratio of the starch (%)**
Afisiafi	89.2	9.8	10.9
Bankye hemmaa	87.8	8.2	9.3
Doku Duade	88.2	10.5	11.9
Control (Hard wheat flour)	81.0	9.2	11.3

Table 9 gives the results from the determination of some important properties of flour and starches in excess water systems.

Table 9. Swelling power, swelling volume, solubility and water-binding capacity of wheat flour and flour from three varieties of cassava mixed in different proportions with wheat flour

Cassava variety	**Proportion of cassava flour (%)**	**Swelling power**	**Swelling volume (ml)**	**Solubility (%)**	**Water-binding capacity (%)**
Afiasiafi	10	8.44	7.6	5.16	87.09
	20	8.57	8	5.37	86.78
	30	9.27	9.3	7.42	87.47
	100	10.48b	8.6ab	12.27a	166.87b
Bankye hemma	10	8.07	8.2	10.38	86.05
	20	7.9	9.3	7.13	84.76
	30	8.51	8	6.26	88.24
	100	10.32b	10.3bc	10.98a	159.46b
Doku Duade	10	7.38	8.3	6.21	81.09
	20	8.54	8.6	6.46	84.66
	30	9.22	8.6	6.56	76.79
	100	12.04b	11c	20.77b	151.97b
Control 100 % wheat		7.65a	7.6a	5.15a	88.43a

Means in column followed by the same letter are not significantly different ($p<0.05$) from each other.

Swelling power in cassava flours ranged from 10.48 to 12.04, swelling volume from 8.6 ml to 11 ml, solubility from 11.0 % to 20.8 % and water-binding capacity from 152.0 % to 166.9 %. The flour from the three cassava varieties had a significantly higher ($p<0.05$) swelling power and water-binding capacity than wheat flour, probably due to a higher starch content in cassava flour (*Table 8*) and a loose association of starch polymers in the cassava starch granule (Eggleston 1993). There were no significant differences in swelling power between the cassava varieties. Apea-Bah *et al* (2011) reported higher values for *Afisiafi* than found in this study. Starches with a high swelling power are less resistant to break down (Apea-Bah *et al* 2011). Eggleston (1993) reported similar results for water-binding capacity. Solubility is an important parameter in baking since flour with a high solubility may give a soggy and less cohesive dough (Apea-Bah *et al*, 2011). Solubility of *Doku Duade* flour was significantly higher than the two other varieties. Solubility of *Afisiafi* flour was similar to that observed by Apea-Bah *et al* (2011).

Figure 2 shows the pasting profile of *Afisiafi* flour, *Bankye hemma* flour and *Doku Duade* flour as well as wheat flour.

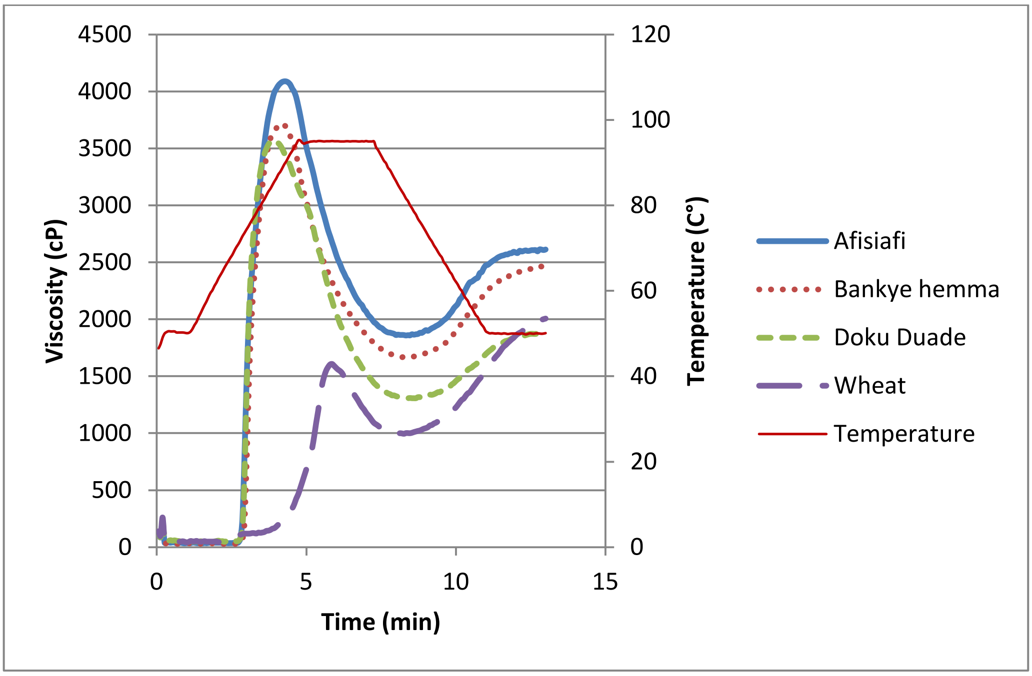

Figure 2: Pasting properties of flour from three varieties of cassava and wheat

The flours from the three cassava varieties were characterized by early gelatinization and showed similar pasting temperature, 70-71 °C. The high peak viscosity (3500 cP for *Doku Duade* to 4089 cP for *Afisiafi*) can be attributed to the high degree of swelling of cassava starch granules (*Table 9*). The rapid drop in viscosity at 95 °C, almost half of the peak viscosity, indicates a large extent of breakdown of the paste and hence low stability. As all cassava flours were high in amylopectin, they exhibited a low retrogradation tendency, showed by a low final viscosity upon cooling, compared to peak viscosity. The final viscosity, a parameter commonly used to determine a sample's ability to form a gel after cooking and cooling, ranged from 1883 cP for *Doku Duade* flour to 2613 cP for *Afisiafi* flour. Wheat flour showed a later increase in viscosity (and thus higher pasting temperature) and lower peak viscosity compared to cassava flours. A higher setback was also observed for wheat flour, since the final viscosity was relatively higher. Cassava flour has rheological properties that differ slightly from those of cassava starch since flour contains fibers, small amounts of lipids and sugars (Moorthy *et al*, 1996). Moorthy *et al* (1996) found that cassava starch cooks to a more cohesive paste and that the presence of fibers in flour delays gelatinization and gives a lower peak viscosity by limiting the access of water into the granules.

Figure 3 shows the pasting properties of blends of wheat and *Afisiafi* flour that were used to bake the bread samples. It shows that the peak viscosities between 100 % wheat flour and the different inclusion levels of cassava flour up to 30 % were quite similar. The onset of gelatinization was occurring faster for flours with a high inclusion level of cassava while the viscosity rise was more progressive for 100 % wheat flour. There was also a lower retrogradation tendency as the proportion of cassava flour increased.

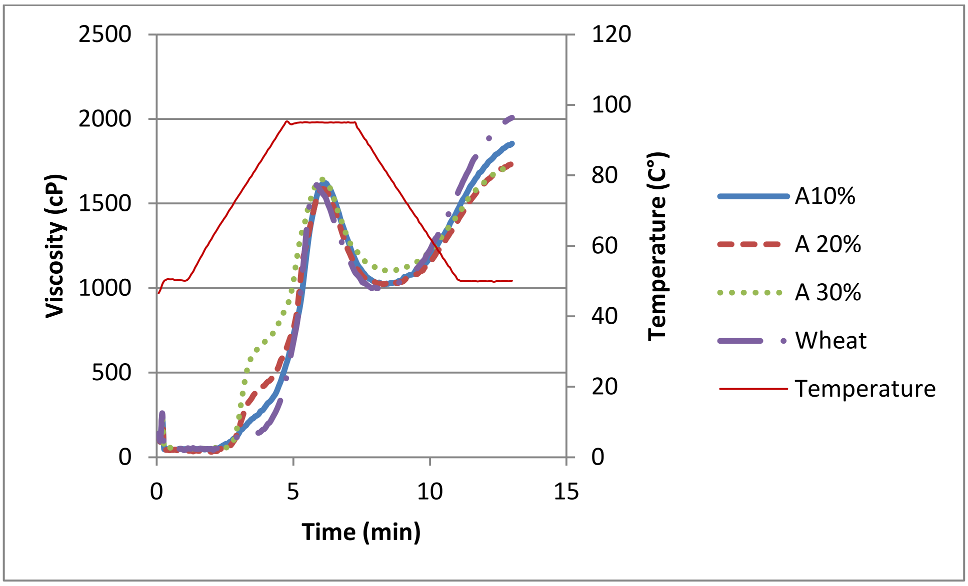

Figure 3: Pasting properties of wheat/cassava flours containing 10, 20 and 30% cassava (Afisiafi) flour.

In several studies concerning cassava flour in composite bread (Ciacco and D'Appolonia, 1976; Almazan 1990; Eggleston *et al*, 1993), no correlation between various physico-chemical properties of cassava flour and starch and bread quality such as loaf volume was established.

4.3. Baking capacity of cassava flour

Specific volume and density of composite wheat/cassava bread

Results from the determination of specific volume and density of the bread samples are given in *Table 10*.

Table 10: Specific volume and density of bread samples baked with flour from three cassava varieties

Cassava variety	Proportion of cassava flour (%)	Specific volume (cm^3/g)	Density (g/cm^3)
Afisiafi	10	3.43a	0.29a
	20	3.25b	0.31b
	30	3.18bc	0.31bc
Bankye hemmaa	10	3.07cd	0.33cd
	20	2.74e	0.36e
	30	2.41f	0.41f
Doku Duade	10	3.41a	0.29a
	20	3.13bc	0.32bc
	30	2.97d	0.34d
Control 100 % wheat		3.46a	0.29a

Means in column followed by the same letter are not significantly different ($p<0.05$) from each other.

Specific volume of breads made from composite wheat/cassava flour decreased significantly ($p<0.05$) with increasing proportion of cassava flour, ranging from 3.07 to 3.43 cm^3/g for 10% substitution level, 2.74 to 3.25 cm^3/g for 20% and 2.41 to 3.18 for 30%. Highest bread specific volumes were obtained with 10% A flour and 10% D flour and they did not differ significantly from the control bread made of 100% hard wheat. Breads made with 20% and 30% B flour had a significantly lower specific volume than the other bread samples with the same substitution level. At the highest percentage of cassava flour (30%), there were significant differences in specific volume between the three varieties. Breads made with A flour showed the highest specific volume that was comparable to that of breads baked with 10% B and 20% D flour. This confirms the findings of Almazan (1990) who observed a significant genotypic effect on cassava/wheat composite bread quality, especially at high cassava flour concentrations. In the present study, differences in specific volume between varieties could not be explained by differences in starch content.

The same trend was observed for the density, since specific volume and density are directly related. Density of bread samples increased significantly ($p>0.05$) with increasing proportion of cassava flour, ranging from 0.29 to 0.33 g/cm^3 for 10% substitution level, 0.31 to 0.36 g/cm^3 for 20% and 0.31 to 0.41 for 30 % (*Table 10*). There was no significant difference between bread loaf density of the control and the breads made with 10 % A flour and 10 % D flour.

The significant decrease in composite bread loaf specific volume with increasing concentration of cassava flour in the samples was also observed by Ciacco and D'Appolonia (1978), Almazan (1990), Eggleston (1993) and Aboaba and Obakpolor (2010). Loaf volume is affected by the quantity and quality of protein in the flour used for baking and also by proofing time, baking time and baking temperature (Shittu, 2007). Since the protein content of hard wheat flour was not labeled and the protein content of cassava flours was not determined, total protein of flour blends could not be calculated. However, cassava flour has a low content of total protein and is not able to form a gluten network in the dough during mixing of flour and water. As the concentration of cassava flour was increased in the wheat/cassava flour dough, the concentration of wheat gluten was decreased. Gluten is responsible for the dough elasticity and allows it to extend during fermentation and baking in oven by trapping the carbon dioxide produced by the yeast. At the high temperature during baking, gluten proteins coagulate and form a relatively rigid skeleton that gives the bread loaf a structure that does not collapse (Mongi *et al* 2011). Thus, an increased substitution level of wheat flour with cassava flour would give a weaker and less elastic dough and a reduction in the leavening ability, resulting in a bread with lower loaf volume and higher density. Aboaba and Obakpolor (2010) found that an inclusion of cassava flour beyond 20 % significantly reduced the leavening profile of the dough in accordance with the present study.

The weakening of the dough with increasing proportion of cassava flour was also observed by Ciacco and D'Apollonia (1978), Eggleston *et al* (1993) and Ninjin *et al* (2011) who analyzed farinograph data on composite wheat/cassava dough. They reported a decreased dough development time as the level of cassava flour increased. Dough development time is the time needed for the paste to reach its maximum consistency before gluten begins to break down (Ninjin *et al*, 2011). A shorter development time thus reflects a lower gluten strength and a faster water uptake by the components present in the flour (Eggleston *et al*, 1993). This is confirmed by the higher water absorption observed as the level of cassava flour in the dough increased and may be correlated to a higher amount of damaged starch in cassava flour and its higher water-binding capacity compared to wheat flour. The authors also found that dough stability decreased with an increased concentration of cassava flour. Dough stability is a good indicator of dough strength as it corresponds to the time during which the dough can resist mixing before it breaks down (Eggleston *et al*, 1993). However, Ciacco and D'Appolonia (1978) observed that dough from flour blends containing cassava starch showed a better baking response than those with cassava flour with a higher dough stability. In addition, Defloor *et al* (1995) found that bread had a drier crumb with a finer structure when cassava starch was used instead of cassava flour. Cassava starch also gave the bread crumb a more pleasant colour and taste due to its absence of fibre and low content of ashes, making it more appropriate than cassava flour in bakery (Ninjin *et al*, 2011). However, Moorthy *et al* (1996) stated that cassava flour is more appropriate than starch for use in products where a nonsticky consistency is desirable.

Texture

The results from the Texture Analyser are given in *Table 11*. An increase in bread hardness with increasing amount of cassava flour was observed and all the samples had a harder texture than the control bread made from 100% wheat flour.

Table 11: Hardness of wheat/cassava bread samples

Variety	Proportion of cassava flour (%)	Peak force (N)
Afisiafi	10	25.6
	20	32.2
	30	37.2
Bankye hemmaa	10	22.0
	20	34.7
	30	48.7
Doku Duade	10	33.4
	20	71.4
	30	90.9
Control 100 % hard wheat		14.6

4.4. Sensory evaluation of composite wheat/cassava bread and cake

The mean scores given by the sensory panel for appearance, taste, texture and overall acceptability of composite wheat/cassava bread are presented in *Table 12*.

Table 12: Mean score for hedonic sensory attributes of wheat/cassava bread samples

Variety	Proportion of cassava flour (%)	Appearance	Taste	Texture	Overall acceptability
Afisiafi	10	8.05a	8.15a	8a	8a
	20	7.55ab	6.8cde	6.9de	6.85cd
	30	7.35b	7.2bcd	6.95cde	7.05bcd
Bankye hemmaa	10	7.6ab	7.45ab	7.1bcde	7.5abc
	20	7.6ab	7.5ab	7.25bcd	7.35abc
	30	6.6c	6.55de	6.4ef	6.5de
Doku Duade	10	7.8ab	7.75ab	7.65abc	7.6ab
	20	7.8ab	7.6ab	7.35abcd	7.65ab
	30	6.35c	6.35e	5.85f	6.1e
Control 100 % hard wheat		7.83ab	7.7ab	7.75ab	7.75a

Means in columns followed by the same letter are not significantly different ($p<0.05$) from each other.

The mean score for overall acceptability on a 9-point scale ranged from 6.1 to 8 for all samples (*Table 12*). The bread samples that did not differ significantly ($p<0.05$) from the control in overall acceptability were those made with 10% A flour, 10 % and 20 % B flour and 10% and 20% D flour, indicating the most preferred samples. These results are similar to those obtained by Eddy *et al* (2007) and Aboaba and Obakpolor (2010) who reported that bread baked with 10 and 20% cassava/wheat composite flour were not significantly different in all sensory attributes, acceptability and in the readiness to buy compared to the control. They also found that bread baked from 30% composite flour and above showed low mean scores to all the attributes. Especially the loaf size and texture, colour of the crust and taste were the most undesirable attributes for bread baked with high cassava flour concentrations (Aboaba and Obakpolor, 2010). The appearance was quite uniformly rated since only 30% B and 30% D samples obtained a significantly lower score compared to the control. In terms of taste, samples baked with 20 % A, 30 % B and 30 % D differed from the control, the remaining samples showing a comparable taste than the control. The rating of texture showed a greater variability since four of the samples (20 % A, 30 % A, 30 % B and 30 % D) obtained a significantly lower score than the control.

The results showed how an increased concentration of cassava flour within the same variety affects the rating of the sensory attributes. For breads made with *Afisiafi*, 10 % A obtained a significantly higher score for all sensory attributes than 20% A and 30% A samples, for which the panel did not observe any significant differences. Breads made with 10% B and 20% B obtained a similar score, which differed significantly from 30% B that was given a significantly lower score for all attributes. The same trend was observed for breads made with D flour, where 30% D got a significantly lower score than 10 and 20% D for all attributes. The general trend was that an increased amount of cassava flour decreased the score for all sensory attributes. This trend was also observed by Almazan (1990) who reported that the total score for volume, colour and character of the crust, texture and grain, crumb colour and taste significantly decreased as the concentration of cassava flour increased. Aboaba and Obakpolor (2010) showed that an increasing amount of cassava flour affected the appearance of the bread crust and noticed a paler crust colour in samples containing high concentrations of cassava flour (30 and 40%). This can be attributed to the whiter colour of cassava flour compared to wheat flour. The significantly lower score for texture obtained by bread samples with 30% cassava flour of all varieties can be attributed to the harder texture that was measured and the significantly higher density determined previously. This is confirmed by the general comments expressed by the panelists for bread samples containing 30% cassava flour. The texture was considered as more “compact”, “sticky”, “heavy” and “brittle”. It had the crust and harder crumb structure of “cake”, “doughnut” or “rock bun” rather than usual white wheat bread. Nevertheless, the samples were acceptable since the texture scores ranged from 5.85 to 6.95 which corresponds to “like slightly” and “like moderately”. In terms of taste, the lower values obtained for 20 % A, 30% B and 30% D can be explained by a “slight bitterness” detected by the panelists.

The cassava variety used affected the bread appearance, taste and texture at the same flour substitution level (*Table 12*). For breads with 10% cassava flour, there were no significant differences between the varieties for all sensory attributes. In 20 % breads, the taste of 20% A was less preferred by the panel compared to 20% B and D, while the other attributes were similar. At 30 % substitution level, 30 % A obtained a significantly higher score for appearance while 30% D obtained the lowest score in terms of taste and texture. There were thus slight differences in the score for sensory attributes between the three cassava varieties, which appeared more significant for 30 % substitution level than for lower levels.

The scores obtained for overall acceptability correspond to a degree of liking from “slightly” to “very much” and indicate that the bread samples were generally appreciated by the panelists. The relatively high amount of shortening and sugar in the bread recipe may have contributed to a pleasant taste (Appendix 2). It is also well recognized that addition of fat plasticizes dough and increases bread volume, typically by 10 %. It makes bread stay soft and more palatable for a longer period of time (Delcour and Hoseney, 2010). With a relatively high percentage of fat and sugar, it is possible to increase the level of non-wheat flour considerably without significant changes in the bread characteristics (Aboaba and Obakpolor, 2010).

The mean scores given by the sensory panel for appearance, taste, texture and overall acceptability of composite wheat/cassava cake are presented in *Table 13*.

Table 13: Mean score for hedonic sensory attributes of wheat/cassava cake samples

Variety	Proportion of cassava flour (%)	Appearance	Taste	Texture	Overall acceptability
Afisiafi	10	7.50a	7.35ab	7.30ab	7.55a
	20	7.60a	7.40ab	7.00a	7.35a
	30	7.50a	7.20a	7.2ab	7.35a
Bankye hemmaa	10	7.75ab	7.90ab	7.8ab	7.95a
	20	7.65a	8.00b	8.00b	7.85a
	30	7.60a	7.45ab	7.55ab	7.40a
Doku Duade	10	7.95ab	7.6ab	7.30ab	7.40a
	20	7.90ab	7.45ab	7.40ab	7.40a
	30	8.30b	7.85ab	7.70ab	7.75a
Control 100 % soft wheat		7.77ab	7.83ab	7.60ab	7.62a

Means in columns followed by the same letter are not significantly different (p<0.05) from each other.

The scores obtained by the cakes showed less variability than those given for the bread samples. No cake sample differed significantly (p<0.05) from the control sample in terms of overall acceptability, appearance, taste or texture, indicating that all cake samples were acceptable. The acceptable level of inclusion of cassava flour in wheat flour thus appeared higher for cakes than for bread. Other studies on inclusion of non-wheat flour in bakery products reported similar results. Sanful and Darko (2010) produced composite rock cakes with 30% cassava/cocoyam flour without any changes in organoleptical properties. Mepba *et al* (2007) found that a ratio of (60:40 w/w) of wheat/plantain flour in biscuits was acceptable. Oluwamukomi *et al* (2011) reported that wheat/cassava biscuits with 40 % cassava flour did not differ from the control in overall acceptability and with addition of 10 % soybean flour, the level could be increased up to 50%.

4.5. Cassava flour as wheat flour substitute in bakery products in Ghana

Increasing urbanization and population in many developing countries as well as changing food habits has resulted in a higher demand for processed food and wheat-based convenience foods (Falade and Akingbala, 2008). For the past decades, the consumption of wheat bread has risen dramatically in Ghana and bread has become a staple food, mainly eaten for breakfast (Aboaba and Obakpolor, 2010). The Ghanaian consumer prefers white and bulky bread loaves baked with high quality hard wheat flour (Rondon and Ashitey, 2011). There has also been a rapid increase in the demand for bakery and pastry products such as biscuits, pies and rock cakes (Sanful and Darko, 2010; FAO 2004). As a result, many tropical countries were wheat is not grown, have to rely on expensive wheat imports paid with foreign currency, which increases dependence on foreign country for their bread production (Eggleston *et al*, 1993). Ghana imports all its wheat from Canada (accounting for 70 % of market share), Argentina, and the European Union (EU) (Rondon and Ashitey, 2011). Since 1980, the imports of wheat in Ghana have risen to reach 300 000 tonnes per year in the nineties. The Ministry of Food and Agriculture (2005) estimated the market of imported wheat flour at 250 000 to 300 000 tonnes per annum. The high cost of hard wheat has resulted in a decline of wheat imports from 350 000 tonnes in 2010-2011 to estimated 300 000 tonnes in 2011-2012. The wheat is milled locally into flour by one of the three major wheat-milling companies in Ghana and since 2010, it is mandatory for all wheat flour produced in Ghana to be fortified with micronutrients (Vitamin A, B1, B2 B6, Nacin, Folic Acid, Iron and zinc) (Rondon and Ashitey, 2011). The wheat market was previously controlled by the government but liberalization has given the millers the possibility to choose wheat suppliers independently on the world market (FAO, 2004). The consumption of wheat in Ghana is estimated to 12.5 kg/capita and it is likely to remain stagnant due to raising flour and bread prices. Production of bread stands for almost 80 % of wheat flour consumption and 20 % is used for cakes and other pastries (Rondon and Ashitey, 2011).

Increasing wheat prices have encouraged food manufacturers to look for alternatives to wheat flour (FAO, 2004). Indigenous crops providing a local source of flour include tropical tubers such cassava, yam, cocoyam, sweet potato and cereals such as maize, rice, sorghum and millet (Falade and Akingbala, 2008). Cassava flour appears suitable as partial substitution of wheat flour due to its availability and existing processing technologies (FAO, 2004). The largest market potential for unfermented cassava flour in Ghana lies in food applications, the most promising food products for inclusion of cassava flour being pies/pastries, cakes, biscuits and doughnuts (MOFA, 2005). Several market acceptability studies in Greater Accra conducted in the late nineties clearly showed that composite flour with an inclusion level of 20 % cassava flour was widely accepted among urban consumers (MOFA, 2005). Utilization of High Quality Cassava Flour for production of baked goods would help to lower the dependency on wheat import and save foreign exchange (Eddy *et al*, 2007). In addition, utilization of HQCF has potential to promote cassava production and contribute to socio-economical development by increasing income and creating job opportunities for the people involved in the Ghanaian cassava sector such as farmers and processors (RTIP, 2008). With a 10% replacement level of imported wheat flour with HQCF, the market potential would be 90 000 tonnes of fresh cassava (Dziedzoave *et al*, 2006). Thus, only a small percent of current cassava production in Ghana is needed for the wheat replacement market (FAO, 2004).

Governments in several cassava-growing nations have made efforts to promote increased production, competitive processing and market diversification of cassava products (Dziedzoave *et al*, 2006). CSIR Food Research Institute in Ghana is involved in the Cassava: Adding Value for Africa (CAVA) Project that was initiated in 2008 to develop value chains for HQCF in Ghana, Tanzania, Uganda, Nigeria and Malawi. The main goal is to improve the livelihoods and income of small-scale cassava farmers and processors, including women and disadvantaged groups, by promoting the use of HQCF as a raw material for the food and non-food industries. The project focuses on ensuring a consistent supply of raw materials, developing viable intermediaries in the value chain and driving market demand in for example the bakery industry (Odedina and Adebayo, 2012). Furthermore, since 1996, CSIR-FRI together with Natural Resources Institute and University of Ghana has been working with biscuits manufacturers and small bakeries in Accra to demonstrate how HQCF can be incorporated in biscuits and cakes at an economic price and that products made with composite flour will be acceptable among consumers. The project has also examined various processing methods for low cyanide cassava varieties, such as chipping, grating and sun and artificial drying.

Commercial production of HQCF is relatively new in Africa and is still used mainly by small and medium-scale processors (Dziedzoave *et al*, 2006). Despite considerable research on bread making technology using composite wheat/cassava flour, the uptake of HQCF by food manufacturers has been limited (MOFA, 2005). In Nigeria for example, 3 tonnes of cassava was used per year by the food industries in the late nineties, which is considered insignificant compared to maize with 133 000 tonnes (Nweke, 2005). Processors have found it difficult to achieve safety standards as well as the quantity, quality, and regularity of supply required by industrial end users (Dziedzoave *et al*, 2006). Large-scale food manufacturers have expressed concern over the quality of cassava flour and consumer acceptability, due to the fact that cassava flour in the past has been associated with quality defects such as inadequate drying, microbial contamination, low pH and unpleasant taste, odour and color or unacceptable levels of toxic cyanogenic glucosides (FAO, 2004). To protect consumers and make HQCF a competitive product on the national and international market, implementation of quality management systems and good manufacturing practices for processing, packaging, storage, transportation and distribution of HQCF is required (Dziedzoave *et al*, 2006).

However, cassava flour of standard high quality may become more expensive and thus increase the cost of the composite flour food products (Nweke, 2005). The uptake of High Quality Cassava Flour by the food industry will depend on an array of economic factors such as raw material price that shows high seasonal variations, processing and drying methods used, transportation costs and access to credit, which will affect selling price of HQCF to end users (FAO, 2004). It will also depend on the price of wheat on the market. The price of a kilo of HQCF should be competitive to that of wheat flour. According to Falade and Akingbala (2008), bakers in Nigeria have replaced wheat flour for cassava flour at 5-20% levels for baked goods with increased profit as a result of the lower cost of HQCF compared to wheat. According to FAO (2004), production trials of cassava flour have shown that it could be produced for between US$ 0.13/kg and US$0.22/kg, compared to the wheat flour price of US$ 1.30/kg, giving small bakers a cost saving of 32 % for manufacturing of biscuits with 35 % inclusion of cassava flour.

The major constraints to production, continuous availability and utilization of HQCF are mainly related to the quality of cassava roots, transportation and processing (FAO, 2004). These include high cost and inadequate supply of fresh cassava, dependence of weather for drying and insufficient drying space, lack of power for processing equipment and high transportation cost on bad roads. Unstable selling prices for HQCF and low market demand are other important factors that explain the reticence of many potential processors of cassava flour (FAO, 2004; Falade, 2008). The successful utilization of HQCF by the food industry requires reliable supply of cassava flour with constant quality and active support from the potential end users of cassava flour who need to demonstrate that a market exists for the product, and to set standards for production (FAO, 2004). It is also probable that cassava flour may be more popular among the informal producers of snack foods as they have lower quality requirements compared to large-scale food processors (MOFA, 2005). The use of cassava flour as partial substitute for wheat flour is likely to increase if it can result in lower prices for manufactured composite cassava/wheat products compared to 100% wheat products (Nweke, 2005).

5. Conclusion

The results showed that the processing of cassava into flour using grating and sun-drying resulted in an acceptable flour yield. The flours obtained had satisfying quality attributes in terms of moisture content and pH. Cassava flour had a whiter colour and higher swelling power, solubility and water-binding capacity than the wheat flour conventionally used for bread baking. This was attributed to a higher starch content in cassava flour and also looser association of starch molecules in cassava starch granules. These functional properties of the starch also affected the pasting profile since cassava flours exhibited an early gelatinization, high peak viscosity, large paste breakdown and low retrogradation tendency compared to wheat flour.

The results from the baking tests showed that an increased proportion of cassava flour in wheat/cassava composite bread reduced loaf specific volume and increased loaf density and hardness due to a reduction of wheat proportion and thus of gluten-forming proteins in the flour blends. The weakening of the dough resulted in a reduced leavening ability and loaf size. A substitution level of 10 to 20% cassava flour in composite bread depending on the variety was acceptable in terms of appearance, taste and texture since it was not perceived as different from 100% wheat bread by the panelists. A higher concentration of cassava flour (30%) was accepted in composite cakes.

There were no significant differences between the flours from different cassava varieties in terms of physico-chemical properties. *Afisiafi* and *Doku Duade* gave loaves with higher specific volume than *Bankye hemmaa* but for 10% substitution level, there was no difference in overall acceptability. Other factors such as age of roots, season at harvest or environmental factors (rainfall) have probably more effect on resulting food products than variety and would be interesting to compare. Also a study of the shelf life of the obtained composite bread loaves may give additional information about bread quality.

High Quality Cassava Flour has potential to succeed for use in bakery products as partial substitute for wheat flour but commercial production and consumption of bread made from composite flour will depend on their price and local acceptance of bread characteristics. Considerable promotion is probably required to drive market demand for composite wheat/cassava products.

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References

AACC (2000). Approved Methods of the American Association of Cereal Chemists. American Association of Cereal Chemists, Inc; St Paul, Minnesota, USA

Aboaba O.O. and Obakpolor E.A. (2010) *The leavening ability of baker's yeast on dough prepared with composite flour (wheat/cassava).* African Journal of Food Science 4: 325 - 329

Almazan A.M. (1990) *Effect of cassava flour variety and concentration on bread loaf quality* Cereal Chemistry 67: 97-99.

Adebowale, A.A., Sanni, L. O., Onitilo, M.O. (2008) *Chemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods.* African Journal of Food Science. 2: 77-82

Apea-Bah F.B., Oduro I., Ellis W.O., Safo-Kantanka O. (2011) *Factor Analysis and Age at Harvest Effect on the Quality of Flour from Four Cassava Varieties*. World Journal of Dairy & Food Sciences 6: 43-54

Bainbridge, Z., K. Tomlins, K. Wellings and A. Wesby (1996). *Methods of Assessing Quality Characteristics of Non-Grain Starch Staples (Part 3-Laboratory Methods).* 1st Edn., Natural Resources Institute, Chatham, UK., 1-70

Balagopalan C., Padmaja G., Nanda S.K. and Moorthy S.M (1988) *Cassava in food, feed, and industry*. CRC Press, Boca Raton, Florida USA

Cardoso A.P., Mirione E., Ernesto M., Massaza F., Cliff J., Haque M.R., J. Bradbury H. (2005) *Processing of cassava roots to remove cyanogens.* Journal of Food Composition and Analysis 18: 451–460. Elsevier

Ciacco C.F. and D'Appolonia B.L. (1978) *Baking studies with Cassava and Yam. II Rheological and baking studies of tuber-wheat flour blends.* Cereal Chemistry 55(4) pp 423-435.

Defloor, I., Leijskens R., Bokanga M., and Delcour J.A. (1994*) Impact of genotype and crop age on the breadmaking and physico-chemical properties of flour produced from cassava (Manihot esculenta Crantz) planted in the dry season.* Journal of the Science of Food and Agriculture 66 pp 193-202.

Defloor I., Leijskens R., Bokanga R., Delcour J.A. (1995) *Impact of genotype, crop age and planting season on the breadmaking and gelatinisation properties of cassava (Manihot esculenta Crantz) Flour.* Journal of the Science of Food and Agriculture 68: 167-174

Defloor I., Dehing I., Delcour J.A. (1998) *Physico-chemical properties of cassava starch.* Starch/Stärke 50: 58-64

Delcour J.A. and Hoseney R.C. (2010) *Principles of Cereal Science and Technology*. 3rd edition. AACC International

Dufour D, Larsonneur S., Alarcón F., Brabet C., Chuzel G (1996) *Improving the bread-making potential of cassava sour starch*. Chapter 16 in Cassava flour and starch: Progress in research and development. Dufour, O'Brien, Best. CIAT Publications No 271. Colombia

Dziedzoave, N.T., Graffham, A.J., Boateng, E.O.(2003) *Training manual for the production of high quality cassava flour*. Food Research Institute (FRI), Accra, Ghana.

Dziedzoave N.T., Abass A.B., Amoa-Awua W.K.A., Sablah M. (2006), *Quality Management Manual for Production of High Quality Cassava Flour.* International Institute of Tropical Agriculture.

Eddy N. O, Udofia, P. G, Eyo, D.(2007) *Sensory evaluation of wheat/cassava composite bread and effect of label information on acceptance and preference.* African Journal of Biotechnology 6 : 2415-2418

Eggleston G., Omoaka P.E., Arowshegbe (1993) *Flour, starch and composite breadmaking quality of various cassava clones.* Journal of the Science of Food and Agriculture 62: 49-59.

Falade K., Akingbala J. (2008) *Improved Nutrition and National Development Through the Utilization of Cassava in Baked Foods*. Chapter 10 from Using Food Science and Technology to Improve Nutrition and Promote National Development, Robertson, G.L. & Lupien, J.R. (Eds), © International Union of Food Science & Technology

Falade K., Akingbala J. (2010): *Utilization of Cassava for Food*, Food Reviews International, 27:1, 51-83

FAO STAT (2011): available http://faostat.fao.org/site/339/default.aspx [2013-01-19]

FAO (2004) *Global cassava market study - Business opportunities for the use of cassava.* Proceedings of the validation forum on the Global Cassava Development Strategy. Volume 6, Food and Agricultural Organization of the United Nations, Rome available http://www.fao.org/docrep/007/y5287e/y5287e00.htm [2012-10-15]

Lawless H.T., Heymann H (1999), *Sensory evaluation of food: principles and practices.* Kluwer Academic/Plenum Publishers, New York.

Leach H. W., McCowen L. D., Schoch T. J. (1959) *Structure of the starch granule*. I. Swelling and solubility patterns of various starches. Cereal Chemistry 36: 534-544.

Medcalf, D.J. and K.A. Gilles, (1965). Wheat starches 1. Comparison of physicochemical properties. Cereal Chem., 42: 558-568

Mepba H.D., Eboh L., Nwaojigwa S.U. (2007) *Chemical composition, functional and baking properties of wheat-plantain composite flours*. African Journal of Food, Agriculture, Nutrition and Development. 7, 1-22

Ministry of Food and Agriculture, Ghana (2005). *Cassava development in Ghana*. A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin. FAO, Rome
available http://www.fao.org/docrep/009/a0154e/A0154E07.htm#ch4 [2012-10-14]

Mongi R.J., Ndabikunze B.K., Chove B.E., Mamiro P., Ruhembe C.C. and JG Ntwenya J.G. (2011) *Proximate composition, bread characteristics and sensory evaluation of cocoyam-wheat composite breads*. African Journal of Food, Agriculture, Nutrition and Development. 11, 5586-5599

Montagnac J.A., Davis R.C., Tanumihardjo S.A. (2009) *Nutritional value of Cassava for use as a staple food and recent advances for improvement.* Comprehensive reviews in food science and food safety. Vol 8. Pp 181-194. Institute of Food technologists.

Moorthy S.N., Rickard J., Blanshard J.M.V. (1996) *Influence of gelatinization characteristics of cassava starch and flour on the textural properties of some food products* Chapter 18 in Cassava flour and starch: Progress in research and development. Dufour, O'Brien, Best. CIAT Publications No 271. Colombia

Nindjin C., Amani G.N., Sindic M. (2011) *Effect of blend levels on composite wheat doughs performance made from yam and cassava native starches and bread quality.* Carbohydrate Polymers 86: pp 1637-1645. Elsevier Ltd

Nweke F. (2005) *The cassava transformation in Africa.* A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin. FAO, Rome
Available http://www.fao.org/docrep/009/a0154e/A0154E02.htm#ch1 [2012-10-22]

Odedina S.A., Adebayo K. (2012) *Commercial Production of Cassava in the Humid Tropics.* Livelihoods support and development centre. Nigeria

Oluwamukomi M.O., Oluwalana, I.B., Akinbowale O.F. (2011) *Physicochemical and sensory properties of wheat/cassava composite biscuit enriched with soy flour.* African Journal of Food Science Vol. 5 (2) pp. 50 – 56. Academic Journals

Rondon M., Ashitey E. (2011) *2011 Grain and Feed Annual – Ghana*, USDA Foreign Agricultural Service. Global Agricultural Information Network

Root and Tuber Improvement Programme RTIP (2004), *Cassava processing in Ghana. An Information guide.* Ministry of Food and Agriculture, Ghana

Sanful R.E, Darko S. (2010) *Production of Cocoyam, Cassava and Wheat Flour Composite Rock Cake.* Pakistan Journal of Nutrition 9 (8): 810-814. Asian Network for Scientific Information

Sakyi-Dawson E,. Lamptey J.A. , Johnson P-N T., Annor G.A. , Budu A. (2006) *Effects of processing method on the chemical composition and rheological properties of flour from four new cassava varieties,* International Union of Food Science and Technology , 947-948

Shittu T.A., A.O. Raji, Sanni L.O. (2007) *Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf*. Food Research International 40, 280–290. Elsevier

Stone H., Sidel J.L. (2004) *Sensory evaluation practices-3rd edition* Food Science and Technology International Series. Elsevier, USA.

UNIFEM (1993). *Root crop processing.* Food Cycle Technology Source Books. Intermediate Technology Publications Ltd, UK

Yamazaki, W.T., (1953). *An alkali water relation test for the evaluation of cooking, baking potentialities of soft water wheat flour*. Cereal Chemistry, 30: 242-246

Åman P., Westerlund E., Theander O. (1994) *Determination of starch using a thermostable α-amylase*. Methods in Carbohydrate Chemistry. Volume X. pp 111-115

Appendix 1

ACCEPTABILITY TEST

Name of Panelist ………………………………..
Date………………..
Product………………………………………..
Sample Code…………………………………

Please before you is a sample of Cassava/Wheat Bread. Using the scale below, please examine it in terms of Appearance, Taste, Texture and Overall Acceptability.

Scale	Interpretation	Appearance	Taste	Texture	Overall Acceptability
9	Like Extremely				
8	Like Very Much				
7	Like Moderately				
6	Like Slightly				
5	Neither like nor Dislike				
4	Dislike Slightly				
3	Dislike Moderately				
2	Dislike Very Much				
1	Dislike Extremely				

Comments……………………………………………………………………………………
…………………………………………………………………………………………………
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Appendix 2

Recipe for Queen cakes

Table: Ingredients used for baking Queen cakes

Ingredients	Quantity
Flour	600 g
Margarine	450 g
Sugar	300 g
Eggs	10 eggs
Milk	60 ml
Baking powder	2 teaspoons
Nutmeg	1 teaspoon

Margarine and sugar were mixed and beaten using an electrical beater for 20-25 min. Eggs were incorporated gradually during constant beating to obtain a fluffy consistence. The dry ingredients were mixed together and added to the egg/margarine/sugar mixture. Finally milk was added and the batter was mixed to incorporate air. Individual cake cups were filled with batter and baked immediately in a hot air oven at 180 °C for 25 min.

Appendix 3

Popular summary in Swedish

Under de senaste årtionderna har ökad befolkning och urbanisering samt ändrade matvanor lett till en större efterfrågan på vetemjölsbaserade livsmedel i många utvecklingsländer, särskilt i storstäderna. Problemet är att eftersom vete inte odlas i det tropiska klimat som råder i de flesta utvecklingsländer tvingas dessa till dyra veteimporter. Detta är fallet i till exempel Ghana i Västafrika som importerar 300 000 ton vete om året från Canada, Argentina och EU för att förse sin befolkning med bröd, bakelser, kex, pajer eller pasta, som egentligen inte tillhör det traditionella köket men som har blivit en del av vardagen. I takt med att priset på vete ökar på den globala marknaden finns det ett intresse av att använda mjöl från lokalt producerade grödor för att minska importberoendet av vete och stödja inhemska lantbrukare.

Kassava framstår i detta fall som ett tänkbart alternativ. Kassava är en mycket utbredd flerårig gröda som odlas i tropiskt klimat. Den är lättskött eftersom den kan växa i näringsfattiga jordar, är tålig mot torka och kan skördas vid valfri tid på året upp till två år efter sådd. I Ghana är kassava en av de viktigaste jordbruksprodukterna när det gäller produktion och energiintag samt i andel av BNP. Kassavarötter innehåller främst vatten och stärkelse, de är energirika och utgör en stapelföda i många utvecklingsländer. Det traditionella sättet att konsumera kassava i Ghana är i form av mjöl som framställs genom att skala och riva rötterna till mindre partiklar som man låter jäsa innan de torkas och mals. Detta mjöl har en lite syrlig smak, blandas ofta med mjöl från andra grödor som majs eller matbanan, kokas med lite vatten och formas till en rund deg som äts med en kryddstark köttgryta. Problem som kan vara kopplade till hög konsumtion av kassava är dess låga proteinhalt och att det kan innehålla ett giftigt ämne som kallas blåsyra. Dock förekommer endast kassavasorter med låg halt blåsyra i Ghana till följd av omsorgsfull selektion. Dessutom försvinner det mesta under processen genom rivning, jäsning eller kokning.

Målet med denna studie var att undersöka möjligheten att ersätta en del av vetemjölet i bageriprodukter med kassavamjöl. I detta fall handlar det om ojäst kassavamjöl s.k. High Quality Cassava Flour som är lämpligare i denna typ av produkter. Studien utfördes vid Food Research Institute i huvudstaden Accra i Ghana. Det är ett statligt forskningsinstitut vars uppdrag är att utveckla nya livsmedelsprodukter från lokala råvaror och förbättra existerande produktionsprocesser. De utför även tjänster åt den lokala livsmedelsindustrin t.ex. bestämning av olika livsmedels innehåll av näringsämnen. I studien undersöktes produktionsprocess samt fysiska och kemiska egenskaper av mjölet från tre olika kassavasorter i jämförelse med det vetemjöl som vanligen används i bakningen. Till exempel mättes vattenhalt, stärkelsehalt, surhetsgrad och vattenbindande förmåga. Även analysen av mjölets viskositet i vatten under upphettning och omrörning under kontrollerade former ger en bild av hur mjölet beter sig i livsmedel under tillagning. Alla dessa värden utgör ett mått på kvaliteten på mjölet. I studien ingick även baktester där bröd och kakor bakades med olika halter av kassavamjöl (10, 20 och 30%) blandat med vetemjöl. Volym, densitet och fasthet mättes på brödet där ett mjukt bröd med hög volym utgjorde den främsta kvalitetskriterien. Brödens volym minskade med ökad andel kassava i mjölblandningen och konsistensen blev fastare. Detta kan förklaras med att kassavamjöl saknar glutenbildande proteiner. Gluten är ett proteinnätverk som formas under blandning och knådning av vetemjöl och vatten och ger degen en elastisk struktur som kan expandera och hålla kvar gasen som bildas under jäsning, vilket ger brödet en större volym. Med minskad proteinhalt i mjölblandningen blir degen svagare och brödet mindre och mer kompakt. En sensorisk panel med 20 konsumenter fick smaka och betygsätta produkternas utseende, smak och konsistens. Resultaten visade att upp till 20% tillsats av kassavamjöl kunde godkännas av panelen eftersom dessa bröd inte skiljde sig från kontrollbrödet bakat på 100% vetemjöl. I kakor kunde 30% kassavamjöl tillsättas utan märkbar skillnad. Dessa resultat innebär att det förmodligen finns en marknad för bageriprodukter med en viss andel kassavamjöl i Ghana. Hur stor framgång dessa produkter får hos livsmedelsindustrin och bland konsumenter kommer bero på priset på kassavamjöl i jämförelse med vetemjöl och därför krävs det sannolikt konkurrenskraftig produktion och förädling av kassava och betydande marknadsföring.