

# Evaluation of Some Physicochemical and Pasting Properties of Three Improved Cassava Varieties Available in the Southeast of Nigeria

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**Abstract:** *Quality attributes of flours from three improved cassava varieties TME 419, TMS 98/87164 and TMS 98/1632 with wheat flour was examined. The Composite flours of the cassava varieties were also evaluated, and level of cassava flour substitution to wheat was from 10 to 30 %. Physicochemical, functional and pasting properties of the flour were evaluated using standard methods. The cyanide content of the flours ranged from 2.04 to 10.42ppm, TTA ranged from 0.05 to 0.45%, while pH ranged from 6.33 to 6.99. Results of functional properties of the flour showed that bulk density ranged from 0.601 to 0.778g/ml; water and oil absorption capacities ranged from 1.00 to 2.85g/ml and 1.17 to 1.87 g/ml respectively, emulsification capacity ranged from 33.33 to 57.91 %, while foam capacity ranged from 1.96 to 35.64 %. Peak viscosity ranged from 62.75 to 251.83 RVU; trough viscosity ranged from 60.58 to 220.08 cP; breakdown viscosity ranged from -60.34 to 127.30RVU; final viscosity ranged from 130.81 to 300.25RVU; Setback viscosity ranged from 36.00 to 194.33RVU, while peak time and pasting temperature ranged from 5.12 to 6.88min and 77.66 to 95.20 °C respectively.*

**Keywords:** *Physicochemical, pasting properties, improved, composite flour.*

## 1. Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important crops in Africa. As a food crop, it fits well into the farming system of small holder farmers in Nigeria because it is available all year

round, thus providing household food security (Ukwuru and Egbeonu, 2013; Linus-Chibuezeh, 2016). The tubers can be kept up to two years in the ground prior to harvesting but once harvested, they begin to deteriorate immediately. Cassava is a root crop which is grown in the tropical and subtropical areas of the world (Burrell, 2003). It serves as the third most important food source in the tropics after cereal crops such as rice, maize etc. It constitutes 60% of the daily calorific needs of the population in tropical and Central America (Osungbaro, *et al.*, 2010). The advantages of cassava as food security crop in sub-Saharan Africa usually outweigh the nutritional draw backs that sometimes make cassava appear as an inferior food. Drawbacks include low protein content, low energy density and the potential toxicity from the presence of the cyanogenic glycosides (linamarin and lotaustrolin) (Dunstan *et al.*, 1996). However traditional technologies have been developed to eliminate the cyanhydric acids in the cassava roots such that they are suitable for human consumption (Osungbaro, 1998; Kobawila *et al.*, 2005). Cassava's increasing importance as food is also derived from its attributes as drought resistant crop and ability to give acceptable yields on low fertility soils.

Cassava production in Nigeria is increasing at three percent every year but Nigeria continues to import starch, flour, sweeteners that can be made from cassava. In Nigeria, the demand for industrial cassava based products such as glucose, dextrose and starch is rising. For instance, about 121,000 metric tonnes of glucose and dextrose was imported in 2008, which was about three times

more than imports in 2002 (Ayodele *et al.*, 2011). The bulk of this demand was met by importation arising from inadequate local production of starch and glucose syrup. This paradox is due to inadequacy in cassava production, processing and marketing. Cassava is produced largely in a subsistence level in the country. To fully exploit cassava's immense potential, especially as a replacement for imported raw materials and as an export commodity, there is a need to change the production technology and trading pattern in the country using a value-chain development approach (Linus-Chibuezeh, 2016). Nigerian cassava-based industrial products are just a fraction of imports, and the growth potential is huge. Productivity and income of various participants in the cassava value chain are inadequate for them to generate increased employment (Oni, 2013). 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 the texture of the end product. In order to be widely accepted by the food industry, cassava flour needs to meet the high quality requirements in terms of physicochemical characteristics, microbial safety and cyanogenic glucoside content (Eriksson *et al.*, 2014). Therefore, the aim of this study was to examine some physicochemical and pasting properties of three improved cassava varieties available in the Southeast of Nigeria.

## 2. Materials and Methods

### 2.1 Processing of Cassava into Flour

Three improved cassava varieties TMS 98/87164, TME 419, and TMS 98/1632 were sourced from the National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria. The method of IITA (2010) for the production of high quality cassava flour (HQCF) was adopted. The cassava roots were processed within 24 h from the time of harvest to drying in order to produce good quality flour that conforms to the set standard. The cassava tubers were cleaned, peeled manually using knives, grated with motorized grater, granulated manually and dried in a cabinet dryer manufactured by Kappa Catering Equipment Italy at 100 °C. The dried cassava mash was milled using a 9FC-360A hammer mill manufactured by JinJuhong machinery, China, and afterwards sieved and stored in black colored high density cellophane bags in a deep freezer until used.

### 2.2 Preparation of Composites

Cassava flour was blended with hard wheat flour [(W) Dangote wheat] at 10, 20 and 30 % inclusion Table 1 for all three varieties of cassava and packaged separately in HDPE (high-density polyethylene) bags for analysis.

**Table 1: Model for flour composites**

Sample	TME 419	TMS 98/87164	TMS 98/1632	Level of wheat flour present (%)
A 10 %	10			90
A 20%	20			80
A 30%	30			70
B 10%		10		90
B 20%		20		80
B 30%		30		70
C 10%			10	90
C 20%			20	80
C 30%			30	70
W	-	-	-	100

### 2.2 Evaluation of Total Cyanide

Cyanogenic glycoside (HCN) of the cassava flour samples was determined by the alkaline picrate method described by Onwuka (2005). Five grams of the sample was dissolved in 50 ml distilled water in corked conical flask, and allowed to stay overnight. The mixture was filtered and the filtrate used for cyanide determination. One milliliter of the sample filtrate and 4 ml alkaline picrate was placed in a corked test tube, and incubated in a water bath for 5 minutes (until visible colour development was observed). Blank was also prepared containing 1 ml distilled water and 4 ml alkaline picrate solution. The absorbance of the coloured mixture and blank was read using a spectrophotometer at 490 nm. The cyanide content was extrapolated from a cyanide standard curve.

### 2.4 pH And Total Titratable Acidity

The pH of the flour samples was measured by making a 10 % (w/v) suspension of each sample in distilled water. The suspensions were mixed thoroughly and the pH measured with a Hanna pH meter (Model HI1270).

The total titratable acidity was carried out in accordance with the method described by AOAC (1995). Distilled water (100 milliliters) was put into a conical flask. Five milliliters of the sample and five drops of phenolphthalein (indicator) were added to the conical flask. The mixture was titrated against 0.01N solution of sodium hydroxide

(NaOH). The end-point was reached when colour change was observed, after adding drops of NaOH solution. % titratable acidity = average titre  $\times$  0.090.

## 2.5 Analysis of Pasting Properties

A Rapid Visco-Analyzer (RVA) (Newport Scientific, Warriewood, Australia) was used to analyze the pasting properties of cassava flours upon heating and subsequent cooling. The RVA General Pasting Method (STD1) was applied. Total running time was 13min and the viscosity values were recorded every 4sec by ThermoLine Software as the temperature increased from 50°C to 95°C before cooling to 50°C again. Rotation speed was set to 960 rpm for the first 10 sec and to 160 rpm until the end. Three grams of flour and 25.0 ml of distilled water were placed in a canister. A paddle was inserted and shaken through the sample before the canister was inserted into the RVA (Newport Scientific, 1998).

## 2.6 Bulk Density

This was carried out by a method described by Onwuka (2005). Ten (10 ml) milliliters capacity graduated measuring cylinder was weighed and the samples gently introduced into it. The bottom of cylinder was gently tapped several times until there was no further diminution of the sample level after filling to the 10 ml mark. The bulk density was calculated as:

$$\text{Bulk density (g/ml)} = \frac{\text{weight of sample (g)}}{\text{volume of sample (ml)}}$$

## 2.7 Water and Oil Absorption Capacities

Method described by Giami *et al.* (1992) was adopted for water and oil absorption capacities determination. One gram of sample was weighed into a graduated centrifuge tube; 10 ml of water or oil was added and thoroughly mixed using a warring blender for 30 seconds. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5,000 rpm for 30 minutes. The volume of free water or oil (supernatant) was read directly from the graduated centrifuge tube. Absorption capacity was expressed as grams of oil or water absorbed (or retained) per gram of sample.

The amount of oil or water absorbed (total minus free) was multiplied by its density for conversion to grams.

## 2.8 Emulsification Capacity

The method described by Onwuka (2005) was followed for emulsification capacity determination. Two grams of flour sample were blended with 25 ml of distilled water in a warring blender for 30 sec at 1600 rpm. After complete dispersion, 25 ml vegetable oil was added and further mixed for 30 sec. The mixture was transferred into a centrifuge tube and centrifuged at 1,600 rpm for 5 min. The volume of oil separated from the sample after centrifuge was read directly from the tube.

## 2.9 Foam Capacity

Foam capacity was determined by methods described by Onwuka (2005). Two grams of flour sample was blended with 100 ml distilled water in a warring blender at 1600 rpm for 5 min. The mixture was transferred into a 250 ml measuring cylinder and the volume recorded after 30 sec. Foam capacity was expressed as percent increase in volume using the formula reported by Abbey and Ibeh (1988).

$$\text{Foam Capacity (\% volume increase or \% whippability)} =$$

$$\frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

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## 3. Results and Discussion

### 3.1 Physicochemical Properties of High Quality Cassava Flour (HQCF) and Wheat Flour

Results of the physicochemical properties of flours are presented in Table 2

The total titratable acidity (TTA) of the flour samples ranged from 0.05 to 0.45 %. The total titratable acidity was higher for control sample of wheat flour compared with the flours of the three cassava varieties, although they were all in acceptable ranges for bakery products. Cassava flour from TME 419 had the highest TTA value compared to other samples, and this was also evident in the higher pH it recorded. However, the TTA of the samples are within the acceptable level of 1.0 % (Abass *et al.*, 1998, Falade and Akingbala, 2008 and Sanni *et al.*, 2006).

The pH of a flour suspension is important since some functional properties such as solubility, emulsifying activity and foaming properties are affected by it. High pH starches have been reported to have increased solubility because of increased

hydrophilic characters of the starch at such pH values (Tsakama *et al.*, 2010). Results obtained in this study, showed pH range of 6.33 to 6.99. The result showed that pH of all the flour samples fell within acceptable standard of 5.5 to 7.0 (ARSO, 2012), with TME 419 having the highest mean value for pH. There was no significant difference ( $p>0.05$ ) between TMS 98/87614 and wheat flour. However, all the flour samples differed significantly from TMS 98/1632 in pH. The pH is a good quality indicator for cassava flour since flour with a pH 4 or less will have a characteristic sour aroma and taste due to fermentation, which is not desirable in bakery products (Apea-Bah *et al.*, 2011).

Hydrogen cyanide in a range of 2.04 to 10.42 ppm was recorded for the cassava varieties while none was recorded for wheat flour. The result showed highest value of HCN of 10.42 ppm for

TME 419 followed by 7.12 ppm for TMS 87164 and 2.04 ppm as the least for TMS 1632. However, the range of cyanogenic glycoside observed in this research fell within acceptable range of 10 ppm considered safe for human consumption (Abass *et al.*, 1998, Falade and Akingbala, 2008 and Sanni *et al.*, 2006), except for TME 419 which is 0.42 ppm higher than the set standard.

Hydrogen cyanide (HCN) is the predominant anti-nutrient in cassava tubers and cassava products. It reduces the acceptability of cassava and its products. Cyanogenic glucosides are compounds that yield glucose, hydrogen cyanide and aldehyde or ketone upon hydrolysis with an acid or enzyme. This cyanide could be lethal as it intercalates with cytochrome oxidase for aerobic function. Processing of cassava tubers into flour reduced the threat of cyanide poisoning to a level safe for human consumption (Table 2).

**Table 2: Physicochemical properties of cassava and wheat flours**

Sample/treatment	TTA (%)	pH	HCN (ppm)
TME 419	0.05 <sup>b</sup> ±0.01	6.99 <sup>a</sup> ±0.04	10.42 <sup>a</sup> ±0.43
TMS 98/1632	0.05 <sup>b</sup> ±0.01	6.33 <sup>c</sup> ±0.01	2.04 <sup>c</sup> ±0.65
TMS 98/87164	0.05 <sup>b</sup> ±0.00	6.47 <sup>b</sup> ±0.02	7.12 <sup>b</sup> ±0.42
Wheat	0.45 <sup>a</sup> ±0.22	6.50 <sup>b</sup> ±0.01	ND
LSD	0.447	1.00	1.00

Values are means ± standard deviation of duplicate determinations

a, b, c - means bearing different superscripts in the same column are significantly different ( $p<0.05$ ).

TTA = total titratable acidity, HCN = hydrogen cyanide and ppm = parts per million, ND = not detected.

### 3.2 Functional Properties of Cassava Wheat Blend

Results of the functional properties of the flour blends are presented in Table 3 below.

Bulk density of the flour blends ranged from 0.60 to 0.78g/ml. Composite technology improved the blends also. It was observed that 20% and 30% flour composites of TME 419 with mean values of 0.78 and 0.78g/ml respectively recorded the highest bulk density values. The results revealed no significance ( $p>0.05$ ) with control. Cassava blends compared favorably in bulk density. The higher bulk density of the wheat flour recorded in this study compared with the cassava flour samples is a significant finding as this suggests that wheat flours are heavier than cassava flours. The bulk density of the flours could be used to determine their handling

requirement, because it is the function of mass and volume (Oladunmoye *et al.*, 2010).

A range of 1.00 to 2.85 g/ml and 1.17 to 1.87 g/ml were recorded for water and oil absorption capacities respectively. Higher water absorption capacities were recorded for the flour from the three cassava varieties used compared to wheat flour (Table 3). On the other, higher oil absorption capacity was observed for whole wheat flour compared to cassava flours. The higher WAC of the high quality cassava flours compared with composite flours and wheat samples investigated could be indicative of higher polar amino acid residues of proteins having an affinity for water molecules and this is an advantage for it in this regard. Water absorption capacity is important in bulking and consistency of products as well as in baking application (Niba *et al.*, 2001). Wheat flour had higher oil absorption capacity (OAC) compared with the cassava flour blends. 100 %

TMS 1632 with mean value OAC of 2.85 g/ml is comparable to that of wheat flour ( $p < 0.05$ ), and better in OAC than other cassava flours. This indicates possibilities of better flavour retainer than other flour samples. Water absorption capacity (WAC) measures the ability of flour to absorb water and swell for improved consistency in food (Okezie and Bello, 1988), while oil absorption capacity (OAC) is important because it acts as flavour retainer and increases the mouth feel of foods. The major chemical compositions that enhance the water absorption capacities of flours are proteins and carbohydrates since these constituents contain hydrophilic parts such as polar or charged side chains.

A range of 33.33 to 57.91 % emulsion capacity was recorded in this work; with 100 % TMS 1632 having the highest mean value. All the flour samples recorded higher emulsion values than wheat flour. However, there was significant

difference ( $p < 0.05$ ) in emulsion capacities of the flour samples. Emulsion capacity simply determines the maximum amount of oil that can be emulsified by protein. High emulsion capacities as observed in this research are positive indication that the flour samples could be an excellent emulsifier in various foods (Akobundu *et al.*, 1982). A range of 1.96 to 35.64 % was recorded for the flour samples in foam capacity. It can also be deduced from Table 3 that wheat flour recorded the highest percentage foam capacity value, while cassava flour samples have much lower values of 2.20 %, 1.96 % and 2.51 % for TME 419, TMS 1632 and TMS 87164 respectively. However, flour composition improved the foam capacities of cassava flours to a reasonable percentage. Good foam capacity is a desirable attribute for flours intended for the production of a variety of baked products including bread, cakes, muffins, cookies etc., and also act as functional agents in other food formulations (El-Adawy, 2001).

**Table 3: Functional properties of wheat-cassava flours and composites**

Sample/Treatment	Level of wheat flour (%)	Bulk density (g/ml)	Water Absorption Capacity (g/ml)	Oil Absorption Capacity (g/ml)	Emulsification Capacity (%)	Foam Capacity (%)
Wheat	100	0.77 <sup>ab</sup> ±0.01	1.00 <sup>cd</sup> ±0.00	1.87 <sup>a</sup> ±0.06	39.56 <sup>efg</sup> ±0.95	34.56 <sup>a</sup> ±0.62
100 % TME 419	0	0.74 <sup>abc</sup> ±0.01	2.10 <sup>b</sup> ±0.14	1.41 <sup>abc</sup> ±0.06	44.23 <sup>cd</sup> ±0.53	2.20 <sup>f</sup> ±0.14
10 % TME 419	90	0.77 <sup>ab</sup> ±0.01	1.25 <sup>cd</sup> ±0.07	1.41 <sup>abc</sup> ±0.19	43.34 <sup>cd</sup> ±0.74	17.55 <sup>c</sup> ±0.64
20 % TME 419	80	0.78 <sup>a</sup> ±0.00	1.40 <sup>cd</sup> ±0.01	1.32 <sup>abc</sup> ±0.32	46.36 <sup>bc</sup> ±1.42	13.50 <sup>d</sup> ±0.71
30 % TME 419	70	0.78 <sup>a</sup> ±0.00	1.44 <sup>cd</sup> ±0.03	1.32 <sup>abc</sup> ±0.32	47.76 <sup>b</sup> ±0.65	7.65 <sup>e</sup> ±0.21
100 % TMS 98/1632	0	0.55 <sup>f</sup> ±0.01	2.85 <sup>a</sup> ±0.21	1.80 <sup>ab</sup> ±0.13	57.91 <sup>a</sup> ±2.96	1.96 <sup>f</sup> ±0.00
10 % TMS 98/1632	90	0.63 <sup>def</sup> ±0.01	2.38 <sup>ab</sup> ±0.39	1.63 <sup>abc</sup> ±0.19	36.23 <sup>gh</sup> ±3.16	9.19 <sup>e</sup> ±0.87
20 % TMS 98/1632	80	0.62 <sup>def</sup> ±0.02	2.45 <sup>ab</sup> ±0.50	1.50 <sup>abc</sup> ±0.12	33.33 <sup>h</sup> ±0.00	18.23 <sup>c</sup> ±0.82
30 % TMS 98/1632	70	0.60 <sup>ef</sup> ±0.03	2.50 <sup>ab</sup> ±0.71	1.51 <sup>abc</sup> ±0.22	41.49 <sup>de</sup> ±1.50	16.55 <sup>e</sup> ±1.22
100 % TMS 98/87164	0	0.69 <sup>bcd</sup> ±0.02	2.65 <sup>ab</sup> ±0.21	1.27 <sup>bc</sup> ±0.26	39.75 <sup>ef</sup> ±1.03	2.51 <sup>f</sup> ±0.41
10 % TMS 98/87164	90	0.66 <sup>cde</sup> ±0.12	0.70 <sup>c</sup> ±0.14	1.17 <sup>c</sup> ±0.15	42.47 <sup>de</sup> ±0.11	31.13 <sup>a</sup> ±0.90
20 % TMS 98/87164	80	0.72 <sup>abc</sup> ±0.01	1.00 <sup>cd</sup> ±0.28	1.18 <sup>c</sup> ±0.51	37.55 <sup>fg</sup> ±0.78	35.64 <sup>a</sup> ±0.31
30 % TMS 98/87164	70	0.70 <sup>abcd</sup> ±0.00	1.00 <sup>cd</sup> ±0.28	1.68 <sup>abc</sup> ±0.06	36.26 <sup>gh</sup> ±0.78	29.91 <sup>b</sup> ±1.90
LSD		0.081	0.212	0.076	0.546	0.173

Values are means ± standard deviation of duplicate determinations

a - h means bearing different superscripts in the same column are significantly different ( $p < 0.05$ ).

### 3.3 Pasting Properties of Cassava-Wheat Composite Flours

Results of pasting properties of wheat- cassava flours and composite are presented in Table 4

below. The pasting properties of flours from three different cassava varieties and their composite flours were compared to wheat flour as a control.

Peak viscosity values obtained in this study ranged from 62.75RVU (100% TME 419) to 251.83RVU (30% TMS 98/1632). Values in Table 4 showed that 100% cassava flours recorded higher peak viscosity values compared to wheat flour except 100% TME 419 which had the least recorded value of 62.75 RVU, while 100 % TMS 98/1632 recorded highest value of 191.17 RVU for whole cassava flours. Composition improved the peak viscosity of the flour blends. However, flours from TME 419 recorded values that were generally low in peak viscosity. Higher values of peak viscosity have been reported by Maziya-Dixon *et al.* (2005) for cassava flours. Peak viscosity is often correlated with final product quality. It is the maximum viscosity developed during or soon after heating. It reflects the ability of starch to swell freely before their physical breakdown (Sanni *et al.*, 2004). It has been suggested that high peak viscosity contributes to good texture of paste, which basically depends on high viscosity and moderately high gel strength (Rosenthal *et al.*, 1974). The relatively high peak viscosity exhibited by most of the varieties is indicative that the flour may be suitable for products requiring high gel strength and elasticity. The pasting characteristics reported for cassava starch all show that on attaining the gelatinization temperature, the starch granules undergo a relatively high degree of swelling, resulting in a high peak viscosity, which is followed by rapid paste breakdown (Rickard *et al.*, 1991). Peak viscosity is often correlated with the final product quality, and also provides an indication of the viscous load likely to be encountered during mixing. Flours with high peak viscosity show that the associated forces between the starch molecules are relatively weak. The molecules are able to penetrate their starch granules much easier and the granules swell enormously leading to weakening of associated forces which in turn make them susceptible to breakdown leading to weak gel formation (Etudaiye *et al.*, 2009).

A range of 60.58 cP (100 % TME 419) to 220.08 cP (30% TMS 98/1632) was recorded for Trough or hot paste viscosity (TV). Hot paste viscosity is the viscosity at the end of holding time at 95°C (Harmdok and Noomhorm, 2006). It measures the ability of starch to remain undisrupted when subjected to a long duration of high, constant temperature during processing (Jimoh *et al.*, 2009). Variety affected the trough viscosity of the flour samples with flours from TMS 98/1632 recording higher values even higher than wheat flour. Composition improved the TV values of TME 419, while a sharp decrease was observed for TMS 98/87164. The wide variation in trough viscosity among varieties could be attributed to the extent of starch leaching. Starches which their amylose

portion leaches out into aqueous phase more quickly, have been reported to readily undergo re-association leading to higher trough viscosities (Singh *et al.*, 2006). Higher holding strength of cassava variety TMS 98/1632 could be attributed to strong associative forces between its starch granules (Jimoh *et al.*, 2009).

The value of breakdown (BD) viscosity ranged from -60.34 RVU (30 % TMS 98/87164) to 127.30 RVU (20 % TMS 98/1632). It is a measure of the fragility of starches. Tsakama *et al.* (2010) stated that breakdown viscosity is a measure of the degree of disintegration of granules or paste stability. Four samples with low paste stability or breakdown have very weak cross-linkage within the granules (Oduro *et al.*, 2000). A low breakdown value suggests, as observed for 30 % TMS 98/87164, a more stability under hot condition (Olufunmilola *et al.*, 2009). This is an indication that there is stronger cross-linking within the granules of flours from cassava variety TME 419 which recorded a streamlined low breakdown value among the flour samples.

Final viscosity (Table 4) ranged from 130.81 RVU (wheat flour) to 300.25 RVU (30% TMS 98/1632). There was significant difference ( $p < 0.05$ ) in the final viscosity of the flour samples. The variation in final viscosity could be attributed to difference in amylose content of the flours, and also due to simple kinetic effect of cooling on viscosity and the re-association of starch molecules in the samples (Ikegwu *et al.*, 2009). In terms of 100 % cassava flours, 100 % TMS 98/87164 recorded highest value (247.33 RVU) followed by 100 % TME 419 (230.83 RUV) and 100 % TMS 98/1632 recorded the lest value (224.33 RVU) in final viscosity. However, values recorded for 100 % cassava flours were higher than that of wheat flour (133.81RVU). Osungbaro *et al.* (2010) reported final viscosity of 284.80 RVU for 100 % fermented cassava flour, while Maziya-Dixon *et al.* (2005) reported similar values for 100 % HQCF from cassava varieties of  $\beta$ -carotene-enriched cassava root. Shimelis *et al.* (2006) reported that final viscosity is used to indicate the ability of starch to form various pastes or gels after cooling and that less stability of starch paste is commonly accompanied with high value of breakdown. Final viscosity is the most commonly used parameter to define the quality of a particular sample, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well the resistance of the paste to shear force during stirring. Final viscosity is the change in the viscosity after holding cooked starch at 50 °C and it represents cooked starch stability. It indicates the stability of cooked starch paste in actual use and

ability of a starch to form a paste or gel after cooling (Shimelis *et al.*, 2006).

Setback viscosity ranged from 36.00 RVU (wheat flour) to 194.33 RVU (20 % TME 419). There was significant difference ( $p < 0.05$ ) among the samples in setback viscosity. Low setback viscosity indicates higher resistance to retrogradation (Sanni *et al.*, 2004). These results (Table 4) show that wheat flour recorded the lowest setback viscosity which indicates higher resistance to retrogradation. Flour from TMS 98/1632 shows low setback values compared to other varieties, and it is observed that composition reduced the setback viscosities of the cassava flour to levels which could indicate higher resistance to retrogradation. A higher value is useful if the flour is to be used in domestic products such as fufu, which requires high viscosity and paste stability at low temperature (Oduro *et al.*, 2000). Earlier report by Kim *et al.* (1995) suggested that high setback value is associated with a cohesive paste and vice versa. The setback viscosity is an index of retrogradation. The viscosity after cooling to 50°C represents setback or viscosity of cooked paste. It is a stage where retrogradation or re-ordering of starch molecules occurs. Setback values have been correlated with texture of various products. High setback value is also associated with syneresis, or weeping, during freeze/thaw cycles (Maziya-dixon *et al.*, 2005).

A range of 5.12 min (10% TMS 98/1632) to 6.88 min (100% TME 419) was recorded for peak time. These values are higher than values reported by Maziya-Dixon *et al.* (2005) for 100 % HQCF from

cassava varieties of  $\beta$ -carotene-enriched cassava roots. A long paste peak time may be associated with granules which swell more gradually and thus are not as susceptible to mechanical damage (Wiesenborn *et al.*, 1994). Tsakama *et al.* (2010) reported that flours with short paste peak time have low resistance to swelling and would be expected to swell rapidly and become susceptible to concurrent shear induced disintegration. The peak time which is a measure of the cooking time, and the time at which viscosity peaks (Etudaiye *et al.*, 2009) was within a very close range.

A range of 77.66°C (20% TMS 98/1632) to 95.20°C (wheat flour) (Table 4) was recorded for pasting temperature. These values are similar to the recorded values of 72.7°C and 80.9°C by Aprianita *et al.* (2009) for yam and sweet potato flours respectively. High pasting temperature indicates higher resistance towards swelling (Sandhu and Singh, 2007). The low pasting temperatures exhibited by the different flour samples suggests that they easily formed pastes hence more suitable in most food and non-food industrial processes because of reduced energy costs during production processes. Pasting temperature is a measure of the minimum temperature required to cook a given foodstuff.

The behaviour in pasting characteristics among starches is attributable to differences in amylose content, crystallinity and the presence or absence of amylose-lipid interaction (Eliasson and Gudmundsson, 2006). This effect of cassava flour on the composite flour is explained by the increase in amylose-gluten or amylose-lipid complexes.

**Table 4: Pasting properties of cassava-wheat composite flour**

Sample/Treatment	Level of wheat flour (%)	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Set Back Viscosity (RVU)	Peak Time (Min)	Pasting Temperature (°C)
Wheat	100	133.17 <sup>h</sup>	94.83 <sup>g</sup>	38.33 <sup>e</sup>	130.83 <sup>l</sup>	36.00 <sup>m</sup>	5.73 <sup>c</sup>	95.20 <sup>a</sup>
100 % TME 419	0	62.75 <sup>m</sup>	60.58 <sup>m</sup>	2.17 <sup>l</sup>	230.83 <sup>g</sup>	170.25 <sup>d</sup>	6.88 <sup>a</sup>	94.45 <sup>b</sup>
10 % TME 419	10	66.08 <sup>l</sup>	62.08 <sup>l</sup>	4.00 <sup>j</sup>	235.42 <sup>f</sup>	173.33 <sup>c</sup>	6.62 <sup>a</sup>	91.75 <sup>d</sup>
20 % TME 419	20	66.67 <sup>k</sup>	62.42 <sup>k</sup>	4.25 <sup>i</sup>	256.75 <sup>b</sup>	194.33 <sup>a</sup>	5.75 <sup>c</sup>	92.25 <sup>c</sup>
30 % TME 419	30	69.92 <sup>j</sup>	67.25 <sup>j</sup>	2.67 <sup>k</sup>	250.00 <sup>c</sup>	182.75 <sup>b</sup>	5.58 <sup>cd</sup>	90.24 <sup>e</sup>
100 % TMS 98/1632	0	191.17 <sup>d</sup>	156.01 <sup>c</sup>	35.17 <sup>g</sup>	224.33 <sup>i</sup>	68.33 <sup>i</sup>	5.27 <sup>de</sup>	82.05 <sup>k</sup>
10 % TMS 98/1632	10	197.37 <sup>c</sup>	158.92 <sup>b</sup>	38.45 <sup>d</sup>	249.25 <sup>d</sup>	98.33 <sup>f</sup>	5.12 <sup>e</sup>	83.35 <sup>h</sup>
20 % TMS 98/1632	20	235.88 <sup>b</sup>	108.58 <sup>f</sup>	127.30 <sup>a</sup>	183.42 <sup>j</sup>	74.84 <sup>h</sup>	5.55 <sup>cd</sup>	79.66 <sup>m</sup>
30 % TMS 98/1632	30	251.83 <sup>a</sup>	220.08 <sup>a</sup>	31.75 <sup>h</sup>	300.25 <sup>a</sup>	80.17 <sup>g</sup>	5.50 <sup>cde</sup>	84.25 <sup>f</sup>

100 % TMS 98/87164	0	161.17 <sup>f</sup>	123.25 <sup>d</sup>	37.92 <sup>f</sup>	247.33 <sup>e</sup>	124.08 <sup>e</sup>	5.33d <sup>e</sup>	82.39 <sup>j</sup>
10 % TMS 98/87164	10	119.67 <sup>i</sup>	70.92 <sup>i</sup>	48.75 <sup>b</sup>	126.50 <sup>m</sup>	55.58 <sup>l</sup>	5.33d <sup>e</sup>	81.75 <sup>l</sup>
20 % TMS 98/87164	20	133.50 <sup>e</sup>	85.08 <sup>h</sup>	48.42 <sup>c</sup>	145.25 <sup>k</sup>	60.17 <sup>k</sup>	6.22 <sup>b</sup>	83.36 <sup>e</sup>
30 % TMS 98/87164	30	169.42 <sup>e</sup>	109.08 <sup>e</sup>	-60.34 <sup>m</sup>	230.57 <sup>h</sup>	61.15 <sup>j</sup>	5.22d <sup>e</sup>	82.65 <sup>i</sup>
LSD		1.00	1.00	1.00	1.00	1.00	0.067	1.00

Values are means of triplicate determination.

a - m means bearing different superscripts down the column are significantly different ( $p < 0.05$ ).

#### 4. Conclusion

The flours obtained from the three cassava varieties had good quality parameters. Analysis showed that cassava flours competed favourably with wheat flour, and in some instances were even better. Cassava flours had higher water absorption and emulsification capacities which are desirable in baking. These properties are attributed to higher starch content in cassava flour and also to a loose association of starch molecules in cassava starch granules. The functional properties of the starch 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. Inclusion of wheat flour generally improved the properties of the HQCF resulting in better composite flours. The low cyanide content of the cassava flours reduced the threat of HCN poisoning, as shown in the value recorded for TME 419 (2.04ppm). The three cassava flours had good final and setback viscosities (224.33 to 230.83 RVU for final viscosity and 162.33 to 170.25RVU for setback viscosity) as against 130.83RVU and 36.00RVU recorded for wheat flour for the same parameters. Flour from 100% TMS 98/1632 recorded highest values for Peak and trough (hot paste) viscosities 191.17RUV and 156.01RVU respectively. This is an indication that the flours have the ability to withstand heating and shear stress during processing. The properties of the three cassava varieties showed significant difference ( $p \leq 0.05$ ) in all the parameters evaluated.

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#### 6. 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 Crops-Africa Branch (ISTRAC-AB). Centre International des Conférences, Cotonou, Benin, 11-17 October, 1998.

Abbey, B.W. and Ibeh, G.O. (1988). Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, Walp) flour. *Journal of Food Science*, 53(6): 1775-1778.

Akobundu, E. N. T., Cherry, J.P. and Simmons, J.G. (1982). Chemical, functional and nutritional properties of egusi (*Colocynthis citrullus* L.) seed protein products. *Journal of Food Science*, 49: 829-835

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

Aprianita, A., Purwandari, U., Watson, B. and Vasiljevic, T. (2009). Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. *International Food Research Journal*, 16:507-520

ARSO (2012). African Organization for Standardization. High Quality Cassava Flour – Specification CD-ARS 840 First Edition 2012 Reference No. ARS 840:2012(E) ICS 67.080.20

Association of Official Analytical Chemists (A. O. A. C. 1995). Official methods of analysis Vol. 16th editions, Washington D.C.

Ayodele D, U. Andrew, E. Nnennaya, O. Chijioke, T. Ganiat and S. Lateef (2011). A Report on Cassava Value Chain Analysis in Niger Delta, Foundation for Partnership Initiatives in the Niger Delta (PIND) 1st Floor St. James Building, 167 Ademola Adetokunbo Crescent, Wuse II, Abuja, Nigeria.

Burrell, M. M. (2003). Starch the need for improved quality or quantity, an over view. *Journal of Experimental Botany*, 218:4574-4762

Dustan W.R., Henry T.A., Auld, S.T.M., (1996). Cyanogenesis in Plant. The occurrence of phaseolunatin in cassava (*Manihot aipi* and *Manihot utilissima*). *Proc. Roy. Soc. London*. 78:152-158.



- El-Adawy, T. A. (2001). Characteristics and composition of watermelon, pumpkin, and paprika seed oils and flour. *Journal of Agriculture and Food Chemistry*, 49:1253-1259.
- Eliasson, A. C. and Gudmundsson, M. (2006). Starch: Physicochemical and Functional Aspects. In: Eliasson AC, editor, *Carbohydrates in Food*, 2nd edition. Boca Raton: Taylor & Francis. Pp428.
- Eriksson, E. Koch, K., Tortoe, C., Akonor, P. T. and Oduro-Yeboah, C. (2014). Evaluation of the Physical and Sensory Characteristics of Bread Produced from Three Varieties of Cassava and Wheat Composite Flours. *Food and Public Health*, 4(5): 214-222 DOI: 10.5923/j.fph.20140405.02 Published online at <http://journal.sapub.org/fph>
- Etudaiye, H. A., Nwabueze, T. U. and Sanni, L.O. (2009). Quality of fufu processed from cassava mosaic disease (CMD) resistant varieties. *African Journal of Food Science*, 3(3): 61-67
- Falade, K. O., and Akingbala, J. O. (2008). Improved nutrition and national development through the utilization of Cassava in baked foods. In: Robertson, G.L, Lupien, J.R. (eds). *Using food science and technology to improve nutrition and promote national development*. International Union of Food Science & Technology. Retrieved online from <http://www.iufost.org/publications/books/document/s/chater10FaladeAkingbala.pdf> accessed 8 June 2013
- Giami, S. Y., Amasisi, T. and Ekiyor, G. (1992). Comparison of Bread Making Properties of Composite Flour from Kernels of Toasted and Boiled African Bread fruit (*Treculia African decne*)seeds. *Journal of Raw Material*, 1(1): 16-25.
- Harmdok, R. and Noomhorm, A. (2006). Hydrothermal treatments of rice starch for improvement of rice noodle quality. *LWT-Food of Science and Technology*, 40: 1723-1731.
- IITA (2010). *Cassava in the Tropical Africa*. A reference manual. International Institute of Tropical Agriculture. Wisbech, Baldings and Mansell International.
- Ikegwu, O. J., Nwobasi, V. N., Odoh, M. O and Oledinma, N. U. (2009). Evaluation of the pasting and some functional properties of starch isolated from some improved cassava varieties. *E-journal of Environment, Agriculture and Food Chemistry*, 8(8): 647-665
- Jimoh, K. O., Olurin, T. O. and Aina, O. (2009). Effect of drying methods on the rheological characteristics and colour of yam flours. *African Journal of Biotechnology*, 8(10): 2325-2328.
- Kobawila, S.C, Louembe D, Keleke S; Hounhouigan J, Gamba C.(2005). Reduction of cyanide content during fermentation of cassava roots and leaves to produce bikedi and ntobambodi, two food products from Congo. *African Journal of Biotechnology*, 4(7):689-696
- Kim, Y. S., Wiessenbon, D. P., Orr, P. H. and Grant, L. A. (1995). Screening potato starch for novel properties using differential scanning calorimetry. *Journal of Food Science*, 60: 1060-1065.
- Linus-Chibuezeh, A. (2016). Effects of High Quality Cassava Flour (HQCF) from different Cassava Varieties on the Nutritional Quality of Wheat-Cassava Bread – A Response Surface Analysis. M.Sc thesis submitted to the Postgraduate School, Michael Okpara University of Agriculture, Umudike
- Maziya-Dixon, B., Adebowale, A. A., Onabanjo, O. O. and Dixon, A. G. O. (2005). Effect of variety and drying methods on physico-chemical properties of high quality cassava flour from yellow cassava roots. *African Crop Science Conference Proceedings*, 7: 635-641.
- Newport-Scientific (1998). *Operational Manual for the Series 4 Rapid Visco Analyzer*. Newport Scientific Pty, Ltd, Sydney.
- Niba, C. C, Bokanga, M., Jackson, F. I., Schlimme, D. S. and Li, B. W. (2001). Physicochemical properties and starch granular characteristics of flour from various *Manihot esculenta* (cassava) genotype. *Journal of Educational Science*, 67: 1701
- Oduro, L. W. O., Ellis, S. K., Aryeetey, K. and Otoo, J. A. (2000). Pasting characteristics of starch from new varieties of sweet potato. *Tropical Science*, 40:25-28
- Oladunmoye. O. O., Akinoso, R. and Olapade, A. A. (2010). Evaluation of some physical-chemical properties of wheat, cassava, maize and cowpea flours for breadmaking. *Journal of Food Quality*, 33(2010): 693 – 708.
- Okezie, B. O. and Bello, B .O. (1988). Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. *Journal of Food Science*, 53: 450-455.
- Olufunmilola, A. A., Jacob, A. A. and Tajudeen, S. O. (2009). Effect of soaking time on the pasting properties of two cultivars of trifoliate yam (*Dioscorea dumetorum*) flours. *Pakistan Journal of Nutrition*, 8(10): 1537-1539
- Oni T.O. (2013) Evaluation of Income and Employment Generation from Cassava Value Chain in the Nigerian Agricultural Sector. *Asian Journal of Agriculture and Rural Development*, 3 (3): 79-92.
- Onwuka G. I (2005). *Food Analysis and Instrumentation. Theory and Practice*. Naphthali Prints, Lagos, Nigeria.
- Osungbaro, T. O. (1998): Effect of particle sizes of Wet milled maize grains on the rheological characteristics of ogi (fermented Starch Porridge) and Agidi (fermented Maize Starch Gel). *Journal of Tropical Resources*, 14(1):102-109
- Osungbaro, T. O., Jimoh, D. and Osundeyi, E. (2010). Functional and pasting properties of composite Cassava-Sorgum flour Meals. *Agriculture and*

- Biology Journal of North America*, 1(4): 715-720.  
<http://www.scihub.org/ABJNA>
- Rickard, J. E., Asaoka, M. and Blanshard, J. M. V. (1991). The physicochemical properties of cassava starch. *Tropical Science*, 31: 189 – 207.
- Rosenthal, F. R. T., Nakamura, T., Espindola, A. M. C. and Jochimek, M. R. (1974). Structure of starch granules. *Die Starke*, 26: 50-55.
- Sandhu, K. S. and Singh, N. (2007). Some properties of corn starches II: physicochemical, gelatinization, retrogradation, pasting and gel textural properties. *Food Chemistry*, 101: 938-946
- Sanni, L. O., Kosoko, S. B., Adebowale, A. A. and Adeoye, R. J. (2004). The Influence of Palm Oil and Chemical Modification on the Pasting and Sensory Properties of Fufu Flour. *International Journal of Food Properties*, 7(2): 229–237.
- Sanni, L. O., Adebowale, A. A., Filani, T. A, Oyewole, O. B and Westby, A. (2006). Quality of flash and rotary dried fufu flour. *Journal of Food, Agriculture and Environment*, 4(3 and 4): 74-78.
- Shimelis, A. E., Meaza, M. and Rakshit, S. (2006). Physicochemical properties, pasting behavior and functional characteristics of flours and starches from improved Bean (*Phaseolus vulgaris* L.) varieties grown in East Africa. *CIGR eJournal*, 8:1-18.
- Singh, J., McCarthy, O. and Singh, H. (2006). Physicochemical and morphological characteristics of New Zealand Taewa (Maori potato) starches. *Carbohydrate Polymers*, 64: 569-581.
- Tsakama, M., Mwangwela, A. M., Manani, T. A. and Mahungu, N.M. (2010). Physicochemical and pasting properties of starch extracted from eleven sweet potato varieties. *African Journal of Food Science and Technology*, 1 (4): 90-98.
- Ukwuru M.U., Egbonu S.E., (2013). Recent development in cassava-based products research. *Academic Journal of Food Resources*, 1(1), 1-13.
- Wiesenborn, D., Orr, P., Casper, H. and Tacke, B. (1994). Potato starch paste behavior as related to some physical/chemical properties. *Journal of Food Science*, 58:644-6.