British Journal of Applied Science & Technology
4(11): 1609-1621, 2014

SCIENCEDOMAIN *international*
www.sciencedomain.org

Physicochemical, Functional and Pasting Characteristics of Three Varieties of Cassava in Wheat Composite Flours

E. Eriksson[1], K. Koch[1], C. Tortoe[2*], P. T. Akonor[2] and E. Baidoo[2]

[1]Department of Food Science, BioCenter, Swedish University of Agricultural Sciences, P.O. Box 7051, SE-750 07 Uppsala, Sweden.
[2]CSIR-Food Research Institute, P. O. Box M20, Accra, Ghana.

Authors' contributions

This work was carried out in collaboration between all authors. Authors EE, KK, CT, PTA and EB designed the study. Authors CT and PTA and EB performed the statistical analysis. Authors EE, KK, CT, PTA and EB wrote the protocol and the first draft of the manuscript. All authors managed the literature searches, read and further approved the final manuscript.

Original Research Article

Received 21st November 2013
Accepted 23rd January 2014
Published 12th February 2014

ABSTRACT

Aims: The aim of this study was to examine the physicochemical and functional properties of cassava flour and in composite with wheat flour for bakery products.
Study Design: A 3 x 3 factorial design of High Quality Cassava Flour and levels of inclusion in wheat flour were designed for the studies.
Place and Duration of Study: Food Processing and Engineering Division of the CSIR-Food Research Institute, Accra and Department of Food Science, BioCenter, Swedish University of Agricultural Sciences, Uppsala, Sweden between January, 2012 and January 2013.
Methodology: High quality cassava flour was processed from three cassava varieties as *Afisiafi*, *Bankye hemmaa* and *Doku duade*, formulated into composite flours at 10, 20 and 30% inclusion levels with wheat flour. The Physicochemical, functional and pasting properties of the flours were characterized.
Results: Cassava flour appeared whiter and less yellowish had higher pH and lower water activity compared to wheat flour but moisture and starch content of the flours showed no significant differences ($p>0.05$). Flour from only *Doku duade* had significantly igher amylose content than wheat flour. Generally, swelling power, solubility index,

---

**Corresponding author: E-mail: ctortoe@yahoo.co.uk;*

solubility volume and water binding capacity were greater in cassava flours than wheat flour. Increasing trend in these parameters was observed as cassava flour inclusion increased in the composite flour. Pasting performance in RVA showed a higher peak viscosity for cassava flour (3500–4089 cP) but lower paste stability and pasting temperature compared to wheat flour. Peak viscosity of the various composites were however comparable to that wheat flour but increasing cassava fraction resulted in early gelatinization and reduced retrogradation of the composite.

Conclusion: The performance of cassava flour and its composite with wheat shows that it can be successfully adopted to replace a significant fraction of wheat flour.

Keywords: Physicochemical; functional; pasting; cassava; wheat; composite flours.

1. INTRODUCTION

Increasing population, urbanization and changing food habits in recent years has led to an increased demand for wheat-based convenient foods in many developing countries. The use of high quality cassava flour in cassava and wheat composite flours has been one way of addressing this need. Cassava (*Manihot esculenta* Crantz) 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. Cassava is cultivated widely in most parts of Africa and contributes to improve food and livelihood security in many developing countries [1].

In Ghana, cassava is one of the most important crops in terms of production, energy intake, and contribution to Growth Domestic Product. It is considered a food security crop with a great potential for industrial applications [2]. Processing cassava into flour is a value addition for expanding the range of uses of the root crop. The flour has been applied as a raw material for ethanol and other fermented foods [2,3] and has partially replaced wheat flour for food and plywood industries [4,5].

Many efforts have been initiated in several developing countries to promote the use of composite flours for baking [6]. In these flours, a fraction of wheat flour is replaced by flour of locally grown crops such as cassava. For certain products, attempts have been made to completely substitute wheat flour with other flours and entirely alter their recipes [1]. In the past some of these composites have been applied without any foreknowledge of their performance in food systems and has resulted in products with varying consumer acceptability. 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. However, the success of completely or partially replacing wheat flour with cassava flour for bakery and other applications could be better achieved if the cassava flour is adequately characterized in terms of its physicochemical and functional behavior. Probably, composite flours change the functional properties of the finished product [7]. The aim of this study was therefore to examine the physicochemical and functional properties of cassava flour and in composite with wheat flour for bakery products.

2. MATERIALS AND METHODS

2.1 Processing of Cassava into Flour

Three different local cassava varieties, *Afisiafi, Bankye hemmaa* and *Doku duade*, which were six months matured, were purchased from farm gates at Pokuasi, north of Accra, Ghana. The cassava roots were washed in tap water, peeled by hand using stainless steel knives, secondarily washed and grated with a motorized cassava grater (Cassava Grater, CSIR-FRI, Accra, Ghana), The grated cassava was packed in polypropylene sacks and pressed under a manual screw press (Screw Press, CSIR-FRI, Accra, Ghana). The cassava mash was disintegrated in the cassava grater and dried in a solar dryer of temperature 35-48ºC. The dried cassava grits were milled into flour using a disc-attrition mill (Mill Machine, CSIR-FRI, Accra, Ghana). A motorized flour sifter (Flour Sifter, CSIR-FRI, Accra, Ghana) with a 250 µm screen was used to remove fibers and larger particles to obtain fine flour with a uniform particle size. The cassava flour was vacuum packaged using Vacuum Sealer, Audion-Vac VM 150H (A1 Packaging Ltd., London, UK) in air-tight polyethylene bags until subsequent use [8,9].

2.2 Preparation of Composites

Cassava flour was blended with hard wheat flour at 10, 20 and 30% inclusion levels for all three varieties of cassava and packaged separately in HDPE (high-density polyethylene) bags for analysis as shown in Table 1. Commercial hard wheat flour (W) purchased from a commercial store in Accra was used as control.

Table 1. Formulation of cassava in wheat flour blends

Sample	*Afisiafi* (%)	*Bankye hemmaa* (%)	*Doku duade* (%)	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

2.3 Moisture Content and Water Activity

Moisture content was determined in triplicate on wheat flour, *Afisiafi* flour, *Bankye hemmaa* flour and *Doku duade* flour according to standard method [10]. Water activity was measured using standard methods in triplicates with a Rotronic Hygrolab 2 (Rotronic, USA) water activity meter.

2.4 pH and Titratable Acidity

Ten grams of flour sample was weighed into a 250 ml beaker. Distilled water (90ml) was added and mixed well. The mixture was left for 1hr at room temperature. The pH was measured in triplicate using a pH meter (Jenway 3330, UK). The prepared mixture was used for determination of total titratable acidity. Phenolphthalein indicator (4-5 drops) was added to the mixture. 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.

2.5 Starch Content of Flours

The starch content was determined by the method of Åman et al. [11] with some modifications concerning the glucose oxidase reaction and final reagent volume. Flour (40 mg) sample was dissolved in 15 ml of 80% ethanol, placed in a boiling water bath for 30 min, centrifuged for 10 min (900 rpm) 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. Acetate buffer (25 ml, 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 shaken three times during incubation. After cooling to 40ºC, 100 µl amyloglucosidase (diluted 1:9 with 0.1 M acetate buffer) was added in order to degrade the starch into glucose units and the samples were incubated in a 60ºC shaking water bath overnight. After centrifuging (10 min, 900 rpm), 40 µl of supernatant was diluted with distilled water to 1:25 and 3 ml GOPOD (glucose oxidase/peroxidase) from Merck (Bergman and Beving Lab) was added. The sample was placed in 50ºC water bath for 20 min and absorbance was read at 510 nm in UV Spectrophotometer (UV Spectrophotometer, Shimadzu, Japan). Glucose concentration in the flour samples was determined from a standard curve with solutions stretching from 0.025 to 0.100 mg/ml. Starch content was calculated using following formula:

$$\%\, starch\ (dry\ matter) = \frac{[glucose](\frac{mg}{ml})\times 25.15\times 0.9\times 25}{sample\ weight\ (mg,DM)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

2.6 Amylose Content of Flours

One hundred microliters of sample solution composed of approximately 50mg 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 rpm, 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 15min in a boiling water bath for complete dissolution. Five ml of 0.5 % trichloroacetic acid (TCA) and 50 µl iodine solution (1.27 g 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.

2.7 Colour

Colour of the flour was measured with a Minolta CR-310 (Minolta, Japan) Tristimulus colorimeter, recording L*, a* and b* values. The machine was calibrated with a reference white porcelain (L_o^* = 97.63; a_o^* = 0.31 and b_o^* = 4.63), before the determinations. The colour space parameters L* (lightness, ranging from zero (black) to 100 (white), a* (ranging from +60 (red) to -60 (green) and b* (ranging from +60 (yellow) to –60 (blue) were measured in pentuplicate and means±standard error (SE) reported. Hue angle and chroma were calculated from a* and b* values using the following formulae [12]:

$$\text{Hue angle } (^{\circ}) = \arctan (b/a) \quad (2)$$

$$\text{Chroma} = \sqrt{(a^2 + b^2)} \quad (3)$$

2.8 Swelling Power, Swelling Volume and Solubility Index

The swelling power (SP), swelling volume (SV) and solubility index (SI) of all the composite flours were determined based on a modification of the method of Leach et al. [13]. One gram of sample was transferred into a weighed graduated 50 ml centrifuge tube. Distilled water was added to give a total volume of 40 ml. 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 min at 2200 rpm. The supernatant was transferred into a can, dried in a hot air oven (BS Gallenkamp, UK) 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:

$$Swelling\ power = \frac{W_{pellet}}{W_{sample\ dry\ basis} - W_{dried\ residue}} \quad (4)$$

$$Solubility\ (\%) = \frac{W_{dried\ residue}}{W_{sample\ dry\ basis}} \times 100 \quad (5)$$

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.

2.9 Water-binding Capacity

The water-binding capacity (WBC) was determined in triplicate on all the composite flours according to the method of Yamazaki [14] as modified by Medcalf and Gilles [15]. Sample (2.0 g) was dissolved in 40 ml of water in a centrifuge tube. The suspension was agitated for 1 hr at room temperature on a shaker (Grant Instruments, United Kingdom) and centrifuged for 10 min at 2200 rpm. The free water was decanted from the pellet and drained for 10 min. The pellet was weighed and water-binding capacity of the sample was calculated by the formula:

$$WBC = \frac{W_{bound\ water}}{W_{sample}} \times 100 \quad (6)$$

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

2.10 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 13 min and the viscosity values were recorded every 4 sec by Thermocline Software as the temperature increased from 50ºC to 95ºC before cooling to 50ºC 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.

2.11 Statistical Analysis

Experiments were conducted in duplicates unless indicated and 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 data obtained for cassava flours.

3. RESULTS AND DISCUSSION

3.1 Moisture Content, Water Activity, pH and total Titratable Acidity of Flour from Three Cassava Varieties and Wheat Flour

Cassava flours showed 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 (Table 2). Low moisture content and water activity is essential for storage of flour to prevent growth of microorganisms, fermentation and caking [16,17,18]. Moisture uptake during storage may increase water activity and lead to changes in certain chemical and organoleptic properties.

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 [19]. 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 [19]. The authors further reported that the age at harvest also significantly affected the moisture content of cassava flour and correspondingly the water activity. The total titratable acidity was higher for control sample of wheat flour compared with the three cassava flours, although they were all in acceptable ranges for bakery products.

Table 2. 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±0.07	0.61±0.001^{a}	6.85±0.01^{a}	0.37
Bankye hemmaa	11.06±0.19	0.61±0.003^{a}	7.05±0.01^{b}	0.36
Doku duade	10.30±0.33	0.61±0.010^{a}	6.73±0.00^{c}	0.41
Wheat (control)	11.81±0.71	0.68±0.004^{b}	6.42±0.02^{d}	0.45

Mean ± standard error within each column followed by a different letter is significantly different at ($p < 0.05$).

3.2 Colour

An important quality attribute of flour is its colour, which affects appearance and consumer acceptability of products made from it [12]. A high degree of whiteness is desirable according to Van Hal [20]. Flour from the three cassava varieties was whiter (91.43-95.43) compared to wheat flour (89.71), which was slightly more yellowish. The whiteness of cassava flour showed that no fermentation and microbial contamination had occurred in the cassava roots prior to processing into flour. It was also indicative of thorough peeling since natural pigments from peels may affect the colour of flour [20]. The colour of wheat was more intense than the other flours as is indicated by its high chroma value (Table 3). Increased lightness index corresponded with low chroma values. The hue angle values place the flours in the yellow region of the CIE L* C* H* colour space, however, as indicated by the lightness index and chroma, this yellowness is very faint (light and less intense).

In a related study on flour colour, cereal colour greatly affected its flour colour of which efficient removal of seed coat improved its colour [21]. Similar observation was made in this study. As colour is the aesthetic appeal of finished products from flour, reducing sugar and amino acid content of flours greatly affects the colour of finished products made from them.

Table 3. Colour determination of flour from three cassava varieties

Cassava variety	L*	a*	b*	Hue angle	Chroma
Afisiafi	93.97±0.26^{a}	-0.22±0.01^{a}	5.15±0.01^{a}	92.40±0.06^{a}	5.15±0.01^{a}
Bankye hemmaa	91.85±0.17^{b}	-0.31±0.02^{a}	5.16±0.08^{b}	93.43±0.15^{b}	5.17±0.08^{b}
Doku duade	95.43±0.13^{c}	-0.25±0.01^{b}	5.00±0.02^{ab}	92.91±0.07^{c}	4.96±0.02^{b}
Wheat (control)	89.71±0.49^{d}	-0.85±0.04^{c}	9.75±0.08^{c}	94.95±0.18^{d}	9.79±0.08^{c}

Mean ± standard error within each column followed by a different letter is significantly different at ($p < 0.05$).

3.3 Starch and Amylose Content

Starch content of cassava flour ranged from 87.8 to 89.2%, which was higher than the starch content of wheat flour (81.0%) although the difference was not significant (Table 4). Differences between the starch content of the selected flours were not significant ($p < 0.05$). Starch content of the cassava flours were consistent with those found these authors [19,22, 23] while that for wheat confirms the assertion that starch makes up about 80.0% of wheat flour [24].

The amylose content in the cassava flours ranged from 16.3 to 18.9%, where *Afiasi* had significantly lower amylose content ($p < 0.05$) than *Bankye hemmaa* and *Doku duade* (Table 4). Wheat flour amylose content of 22.6% was significantly higher ($p < 0.05$) than all three cassava varieties. On starch-basis, the amylose content obtained for all three varieties of cassava were 18.2% for *Afiasi*, 21.4% for *Bankye hemmaa*, 20.3% for *Doku duade* and 27.9% for wheat. These values were similar to those observed by other authors [25] and [26], who estimated amylose content of cassava starch as 17.0-23.6%. However, starch and amylose content varies from one crop to another and even among same crops of different botanical origin [19,27]. Hung et al. [28] reported the possibility of high amylose flours used to replace 50% wheat flour without a compromise on acceptability when applied in baking.

Table 4. Starch and amylose content

Cassava variety	Starch content (% of flour, dry matter)	Amylose content (% of flour, dry matter)
Afisiafi	89.2 ± 0.01^{c}	16.3 ± 1.45^{a}
Bankye hemmaa	87.8 ± 0.01^{b}	18.8 ± 0.96^{b}
Doku duade	88.2 ± 0.02^{b}	18.9 ± 0.12^{b}
Wheat (control)	81.0 ± 0.02^{a}	22.6 ± 1.4^{c}

Mean ± standard error within each column followed by a different letter is significantly different at ($p < 0.05$).

3.4 Functional Properties of Cassava Flour, Wheat Flour and their Composites

Flour from the three cassava varieties had a significantly higher SP and WBC than wheat flour ($p < 0.05$) (Table 5). It may be a result of the differences in amylopectin content of the various flours since SP has been described as an amylopectin property [29,30]. Furthermore, proteins and lipids, which are present in higher amounts in wheat compared to cassava, inhibit SP [31]. Also, the higher SP in cassava flour than wheat flour reflects the weaker bonding forces in their starch granules [32]. There were no significant differences in SP between the cassava varieties although *Doku duade* exhibited significantly higher solubility. Apart from the solubility of *Bankye hemma*, which defied previously recognized trends, WBC and solubility correlated well with SP for the various flours, as has been observed in earlier studies [31,33]. Differences in WBC observed may be attributed to the variability in available water binding sites among the various flours [34].

Table 5. Functional properties of cassava flour, wheat flour and their composites

Cassava variety	Proportion of cassava flour (%)	Swelling power	Swelling volume (ml)	Solubility (%)	Water-binding capacity(%)
Afisiafi	10	8.44 ± 0.37^{a}	7.67 ± 0.17^{a}	5.16 ± 0.23^{a}	87.09 ± 3.27^{b}
	20	8.57 ± 0.06^{ab}	8.00 ± 0.00^{ab}	5.37 ± 0.31^{ab}	86.78 ± 1.10^{b}
	30	9.27 ± 0.14^{bc}	9.33 ± 0.33^{bc}	7.42 ± 1.37^{ab}	87.47 ± 0.23^{b}
	100	10.48 ± 0.63^{d}	8.67 ± 0.33^{ab}	12.27 ± 3.56^{b}	166.87 ± 4.84^{d}
Bankye hemmaa	10	8.07 ± 0.38^{ab}	8.17 ± 0.44^{ab}	10.38 ± 5.19^{ab}	86.05 ± 1.28^{b}
	20	7.90 ± 0.37^{a}	9.33 ± 0.67^{bc}	7.13 ± 0.79^{ab}	84.76 ± 1.21^{ab}
	30	8.51 ± 0.23^{ab}	8.00 ± 0.50^{ab}	6.26 ± 0.40^{ab}	88.24 ± 1.58^{b}
	100	10.32 ± 0.74^{cd}	10.33 ± 0.88^{cd}	10.98 ± 3.26^{ab}	159.46 ± 5.04^{cd}
Doku duade	10	7.38 ± 0.18^{a}	8.33 ± 0.33^{ab}	6.21 ± 0.48^{ab}	81.09 ± 1.75^{ab}
	20	8.54 ± 0.09^{ab}	8.67 ± 0.33^{ab}	6.46 ± 0.72^{ab}	84.66 ± 2.71^{ab}
	30	9.22 ± 0.23^{bc}	8.67 ± 0.33^{ab}	6.56 ± 1.05^{ab}	76.79 ± 0.49^{a}
	100	12.04 ± 0.55^{e}	11.33 ± 0.33^{b}	20.77 ± 0.58^{c}	151.97 ± 5.21^{c}
Wheat (control)	0	7.65 ± 0.18^{a}	7.67 ± 0.33^{a}	5.15 ± 0.28^{a}	88.43 ± 1.28^{b}

Means ± standard error within each column followed by a different letter is significantly different ($p < 0.05$) from each other.

Generally, increasing the amount of cassava flour in cassava/wheat composite flours resulted in an increase in SP, SV, SI and WBC of the composite flour. The ANOVA for the functional properties on *Afisiafi, Bankye hemmaa* and *Doku duade* flours at 100% and their composite compared to wheat flour is presented in Table 6. Solubilization is a consequence of swelling and occurs after birefringence is lost during gelatinization and amylose leaches out of swollen starch granules [35] while WBC reveals the intermolecular associations between starch polymers [36]. Flour with very high solubility may result in soggy and less cohesive dough when applied in baking [19].

Table 6. ANOVA for functional properties of varietal cassava flour and their composites compared to wheat flour

Cassava variety	***p-value***			
	Swelling power	**Swelling volume (ml)**	**Solubility (%)**	**WBC(%)**
*Afisiafi (*100% and composites*)*	0.002	0.005	0.063	<0.001
*Bankye hemmaa (*100% and composites)	0.009	0.051	0.519	<0.001
*Doku duade (*100% and composites*)*	<0.001	<0.001	<0.001	<0.001
Wheat (control)	–	–	–	–

3.5 Pasting Characteristics

Pasting temperature, which is also related to paste stability, gives an indication of the strength of associative forces within the granules [37]. Flours from the three cassava varieties were characterized by early gelatinization and showed similar pasting temperature of 70-71ºC, which was lower compared to pasting temperature of wheat flour (Fig. 1). This reveals lower gelatinization temperature of cassava starch granules, which translates into shorter cooking time and lower paste stability of cassava flour as opposed to the wheat flour [38,39].

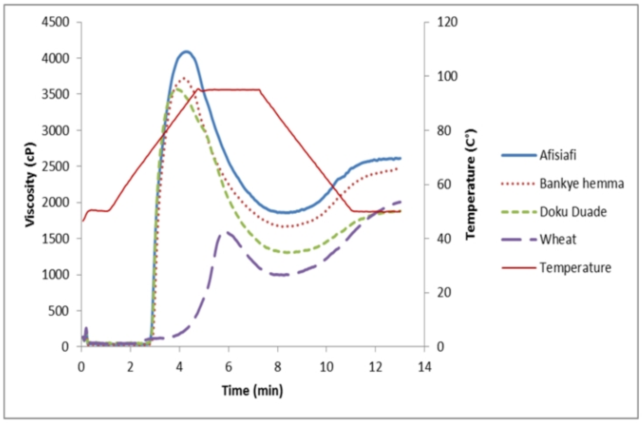

Fig. 1. Pasting profile of flour from wheat and three varieties of cassava

Peak viscosity is indicative of ease of cooking a particular sample. The high peak viscosity of 3500 cP for *Doku duade* compared to 4089 cP for *Afisiafi* can be attributed to the high degree of swelling of cassava starch granules (Fig. 1). The rapid drop in viscosity at 95ºC corresponding to almost half of the peak viscosity suggests a large extent of breakdown of the paste and hence low stability. As all cassava flours were high in amylopectin (≈ 90%), they exhibited a low retrogradation tendency (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 lower peak viscosity compared to cassava flours (Fig. 1). A higher setback was also observed for wheat flour as the final viscosity was relatively higher. These findings confirmed earlier stance that cereal starches have a lower peak viscosity compared to tuber and root starches [40,41].

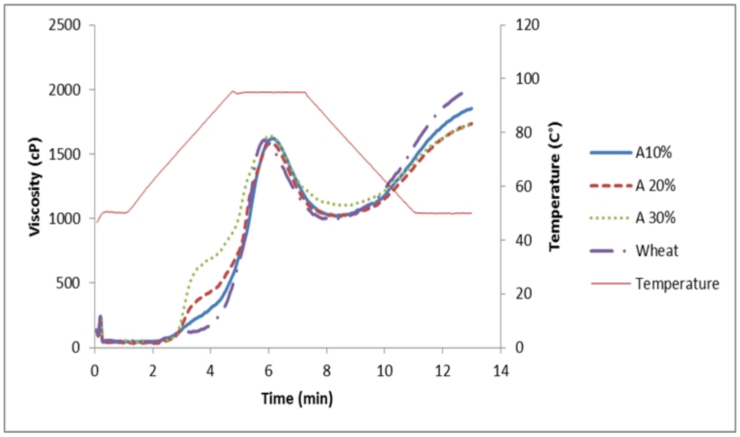

Fig. 2. Pasting properties of wheat/cassava flour (*Afisiafi*) containing 10, 20 and 30% cassava flour

Fig. 2 shows the pasting properties of wheat flour and *Afisiafi*-wheat composite flour at 10%, 20% and 30%, which is supported by Fig. 1 that clearly indicated higher viscosity in *Afisiafi* when all the varietal 100% flours were compared. The pasting profiles of *Afisiafi*-wheat flour composite were verifiably different from *Bankye hemmaa*-wheat and *Doku duade*-wheat composite flours. The addition of cassava flour to wheat affected some pasting properties of the composite flour, although peak viscosities between 100% wheat flour and the different inclusion levels of cassava flour up to 30% were quite similar. The onset of gelatinization occurred faster for flours with a high inclusion level of cassava and retrogradation decreased as proportion of cassava flour increased. Increasing substitution level would be felt very much in the eating quality of foods prepared from this composite flour as the paste stability (50ºC hold) is consistently reduced. Nonetheless, 20% replacement of wheat flour with cassava flour showed paste stability which was akin to 30% substitution level (Fig. 2). This effect of cassava flour on the composite flour is explained by the increase in amylose-gluten or amylose-lipid complexes. The behaviour in pasting characteristics among starches is attributable to differences in amylose content, crystallinity and the presence or absence of amylose-lipid interaction [42,43].

4. CONCLUSION

The flours obtained from the three cassava varieties showed good quality properties. Cassava flour was whiter and had higher swelling power, solubility and water-binding capacity than the wheat flour, which is required for bread baking. These properties are attributed to higher starch content in cassava flour and also to 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. Inclusion of cassava flour generally increased SP, SI, SV and WBC of the resulting composite flour. Gelatinization was faster while retrogradation reduced for composite flours with high level of cassava substitution. Peak viscosity of flours was rather similar to that of wheat flour. The study shows that physicochemical and functional performance of cassava flour from the three cassava varieties can successfully replace portions of wheat flour for application in the bakery industry.

ACKNOWLEDGEMENTS

The first author wishes to thank the Swedish Government for financial support and the CSIR -Food Research Institute for the provision of laboratory facilities for the studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Falade KO, Akingbala JO. Improved nutrition and national development through the utilization of cassava in baked foods. In: Robertson GL, Lupien JR, editors. Using Food science and technology to improve nutrition and promote national development: selected case studies. International Union of Food Science and Technology (IUFoST); 2008.
2. Amoa-Awua WK, Owusu M, Feglo P. Utilization of unfermented cassava flour for the production of an indigenous African fermented food, *agbelima.* World Journal of Microbiology and Biotechnology. 2005;21:1201–1207.
3. Ocloo FCK, Ayernor GS. Physical, chemical and microbiological changes in alcoholic fermentation of sugar syrup from cassava flour. African Journal of Biotechnology. 2008;7:164–168.
4. Westby A. Cassava Utilization, Storage and Small-scale Processing. In: Hillocks RJ, Thresh, JM, Bellotti AC, editors. Cassava: Biology, Production and Utilization. London: CAB International. 2002;281–300.
5. Derkyi NSA, Sekyere D, Darkwa NA, Yartey JG. Effect of cassava flour as urea-formaldehyde adhesive extender on the bonding strength of plywood. Ghana Journal of Forestry. 2008;23&24:25–34.
6. Olaoye OA, Onilude AA, Idowu OA. Quality Characteristics of Bread produced from composite flours of wheat, plantain and soybeans. African Journal of Biotechnology. 2006;5:1102–1106.
7. Adetuyi FO, Badejo OF, Ikujenlola AV, Omosuli SV. Storage influence on the functional properties of malted and unmalted maize (*Zea mays* LSSP mays) and soybean (*Glycine max* L Merill) flour blends. African Journal Food Science. 2009;3:56–60.
8. Barbosa-Canovas G, Vega-Mercado H. Cabinet and bed dryer. In: Chapman Hall ITP, editors. Dehydration of Foods.1st edition. New York: Thompson, EEUU.1996;157-184,256-257.
9. Singh RP, Heldman DR. Introduction to Food Engineering, 3rd edition. Academic Press. San Diego, CA. USA. 2001;565-567.
10. Bainbridge ZK, Tomlins K, Wellings A, Wesby A. Methods of Assessing Quality Characteristics of Non-Grain Starch Staples (Part 3-Laboratory Methods). 1st edition. Chatham: Natural Resources Institute, 1996;1-70.

11. Aman P, Westerlund E, Theander O. Determination of starch using a thermostable α-amylase. Methods for Carbohydrate Chemistry. Volume X. 1994:111-115.
12. Wrolstad RE, Smith DE. Color Analysis. In: Nielsen S, editor. Food Analysis, 4th edition. New York: Springer Science and Business Media, LCC. 2010;573-586.
13. Leach HW, McCowen LD, Schoch TJ. Structure of the starch granule. I. Swelling and solubility patterns of various starches. Cereal Chemistry. 1959;36:534-544.
14. Yamazaki WT. An alkali water relation test for the evaluation of cooking, baking potentialities of soft water wheat flour. Cereal Chemistry. 1953;30:242-246.
15. Medcalf DJ, Gilles KA. Wheat starches I. Comparison of physicochemical properties. Cereal Chemistry. 1965;42:558-568.
16. Aguilera JM, Stanley DW. Microstructural principles of food processing and engineering. 2nd edition. Aspen Publishers Inc., Maryland. 1999;403.
17. Chirife J, Fontana JA. Introduction: Historical highlights of water activity research. In: Barbosa-Canovas G, Fontana JA, Schmidt SJ, Labuza TP, editors. Water Activity in Foods, Fundamentals and Applications. Blackwell Publishing and the Institute of Food Technologists. 2007;3-14.
18. Maltini E, Torreggiani D, Venir E, Bertolo G. Water activity and the preservation of plant foods. Food Chemistry. 2003;82:79–86.
19. Apea-Bah FB, Oduro I, Ellis WO, Safo-Katanka O. Factor analysis and age at harvest effect on the quality of flour from four cassava varieties. World Journal of Dairy Food Science. 2011;6:43–54.
20. Van Hall M. Quality of sweet potato flour during processing and storage. Food Review International. 2000;16:1-37.
21. Taylor JRN, Anyango JO. Sorghum flour and flour products: production, nutritional quality and fortification. In: Preedy VR, Watson RR and Patel VB, editors. Flours and breads and their fortification in health and disease prevention, 1st edition. New York: Academic Press. 2011;127
22. Niba LL, Bokanga MM, Jackson FL, Schlimme DS, Li BW. Physicochemical properties and starch granular characteristics of flour from various *Manihot esculenta* (cassava) genotypes. Journal of Food Science. 2001;67:1701–1705.
23. Nuwamanya E, Baguma Y, Emmambux N, Taylor J, Rubaihayo P. Physicochemical and functional characteristics of cassava starch in Ugandan varieties and their progenies. Journal of Plant Breeding and Crop Science. 2010a;2:1–11.
24. Hermansson AM, Svegmark K. Developments in the understanding of starch functionality. Trends in Food Science and Technology. 1996;7:345–353.
25. Defloor I, Dehing I, Delcour JA. Physico-chemical properties of cassava starch. Starch/Stärke. 1998; 50: 58-64.
26. Nuwamanya E, Baguma Y, Emmambux N, Rubaihayo P. Crystalline and pasting properties of cassava starch are influenced by its molecular properties. African Journal of Food Science. 2010b;4:8–15.
27. Ceballos H, Sanchez T, Morante N, Fregene M, Dufour D, Smith AM, Denyer K, Perez JC, Calle F, Mestres C. Discovery of an amylose-free starch mutant in cassava (*Manihot esculenta* Crantz). Journal of Agricultural and Food Chemistry. 2007;55:7469–7476.
28. Hung PV, Yamamori M. Morita N. Formation of enzyme-resistance starch in bread as Affected by High-Amylose wheat flour substitutions. Cereal Chemistry. 2005;82:690-694
29. Li JY, Yeh AI. Relationship between thermal, rheological characteristics and swelling power for various starches. Journal of Food Engineering. 2001;50:141–148.
30. Wrolstad RE. Food Carbohydrate Chemistry. John Wiley and Sons Inc. and IFT Press, Iowa; 2012.

31. Wang L, Seib PA. Australian salt-noodle flours and their starches compared to US wheat flours and their starches. Cereal Chemistry. 1996;73:167–175.
32. Eggleston G, Omoaka PE, Arowshegbe A. Flour, starch and composite bread making quality of various cassava clones. Journal of the Science of Food and Agriculture. 1993;62:49-59.
33. Srichuwong S, Sunarti TC, Mishima T, Isono N, Hisamatsu M. Starches from different botanical sources II: Contribution of starch structure to swelling and pasting properties. Carbohydrate Polymers. 2005;62:25–34.
34. Wotton M, Bamunuarachchi A. Water binding capacity of commercial produced native and modified starches. Starch/Starke. 1978;33:159–161.
35. Singh N, Sandhu KS, Kaur M. Characterization of starches separated from Indian chickpea (*Cicer arietinum*) cultivars. Journal of Food Engineering. 2004;63:441–449.
36. Rincon AM, Padilla FC, Araujo C. and Tillet SC. *Myrosma canafolia*, chemical composition and physicochemical properties of the extracted starch. Journal of Science Food Agriculture. 1999;79:532–536.
37. Afoakwa EO, Sefa-Dedeh S. Viscoelastic properties and changes in pasting characteristics of trifoliate yam (*Dioscorea dumentorum*) starch after harvest. Food Chemistry. 2002;77:203–208.
38. Afoakwa EO, Adjonu R, Asomaning J. Viscoelastic properties and pasting characteristics of fermented maize: influence of the addition of malted cereals. International Journal of Food Science and Technology. 2010;45:380–386.
39. Baah FD. Characterization of water yam (*Dioscorea alata*) for existing and potential food products. PhD thesis submitted to Faculty of Biosciences. Kumasi-Ghana: Kwame Nkrumah University of Science and Technology; 2009.
40. Biliaderis CG. Structural transitions and related physical properties of starch. In: BeMiller J, Whistler R, editors. Starch: Chemistry and Technology, 3rd edition. New York: Academic Press, 2009;293–372.
41. Van Hung P, Yamamori M, Morita N. Formation of enzyme-resistant starch in bread as affected by high amylose wheat flour substitutions. Cereal Chemistry. 2005;82:690-694.
42. Singh N, Singh P. Amaranth: Potential source of flour enrichment. In: Preedy VR, Watson, RR, Patel VB, editors. Flours and breads and their fortification in health and disease prevention, 1st edition. New York: Academic Press, 2011;101–112.
43. Eliasson AC, Gudmundsson M. Starch: Physicochemical and Functional Aspects. In: Eliasson AC, editor, Carbohydrates in Food, 2nd edition. Boca Raton: Taylor & Francis. 2006;428.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=434&id=5&aid=3599