International Food Research Journal 24(6): 2549-2556 (December 2017)
Journal homepage: *http://www.ifrj.upm.edu.my*

Physicochemical and functional properties of flour from twelve varieties of Ghanaian sweet potatoes

[1*]Tortoe, C., [1]Akonor, P. T., [2]Koch, K., [2]Menzel, C. and [3]Adofo, K.

[1]*CSIR-Food Research Institute, P. O. Box M20, Accra, Ghana*
[2]*Department of Food Science, Swedish University of Agricultural Sciences, P.O. Box 7051, SE-750 07 Uppsala, Sweden*
[3]*CSIR-Crops Research Institute, P. O. Box 3785, Fumesua-Kumasi, Ghana*

Article history

Received: 18 September 2016
Received in revised form: 1 November 2016
Accepted: 4 November 2016

Keywords

Sweet potato
Ipomoea batatas
Varieties
Physicochemical
Functional
Properties

Abstract

Physicochemical and functional properties of flours produced from 12 varieties of sweet potatoes had colour indicating Apomuden (AP) as the darkest (L^* values 83.6) and *Ligri* (GR) as the lightest (L^* values 89.4) of the flours. The moisture content ranges from 7.6 to 10% below 15% specified for flours. Water activity was ranged from 0.5 to 0.6, an indication of shelf-stable flours. The varieties *Faara* (CFA) and *Sauti* (SAT), which had high amounts of moisture were also similar in their water activities. The pH of the flours ranged from 5.8 to 6.2, indicating low acidity. The flours indicated easy-to-cook properties as their pasting temperature was between 79 and 84°C. Peak viscosity ranged between 75 and 304 RVU while setback viscosity ranged from 49 to 148RVU. AP had lower pasting properties but showed the least tendency to retrograde, with a setback ratio of 1.4. *Ligri* (GR) and *Histarch* (HI) showed the highest peak viscosity (304 and 300RVU) whereas flour from *Bohye* (BO) and *Otoo* (OT) were the most stable. The flours possess physicochemical and functional properties that makes them applicable in a wide array of food and industrial purposes.

© All Rights Reserved

Introduction

Sweet potato *(Ipomoea batatas)* is one of the widely grown root crops and provides energy nourishment for more than 100 million people globally. It is drought tolerant, has a short cultivation cycle, requires little external inputs and yields highly, even in areas with relatively marginal edaphic conditions (Ewell, 1993). As a result, sweet potato is considered among the crops with a potential for combating food crisis in Africa. The crop is regarded as the 7th most important food crop globally but ranks 3rd after cassava and yams in terms of quantity produced in Ghana (SRID, 2013). Its importance is reflected in the increase in production quantities over the past decade. It is predominantly cultivated by peasant and small-holder farmers throughout Ghana, with the Upper, Central and Volta regions serving as the leading hubs of production. These three regions account for more than 60% of the 135,000MT of the crop produced in year 2012 (SRID, 2013).

The main importance of sweet potato roots as food is attributable to it being well endowed with easily digestible carbohydrates, which make up nearly 90% of its dry matter. It is a higher source of energy and provides more than 450KJ/100g of energy, compared to other root and tuber staples such as yam and taro. Sweet potato is also an excellent source of other important dietary components. It contains substantial concentrations of carotenes, vitamin B_1 and B_2. The major inorganic elements contained in sweet potatoes are potassium (260mg/100g), phosphorus (51mg/100g) and calcium (29mg/100g) (Woolfe, 1992). In spite of this impressive nutritional profile, the crop is limiting in protein and vitamin C and has received much attention from breeders in order to improve these nutrients. Nutrient composition, nevertheless, varies with genetic and edaphic factors as well as production practices.

Sweet potato roots are difficult to store and can hardly keep longer than a few weeks (Rees *et al.*, 2003; Tomlins *et al.*, 2000), with huge losses reported, especially in seasons of glut (Teye *et al.*, 2011). As a result of this post-harvest instability, the crop has a reduced commercial potential and is eaten within a few days after harvest. Traditionally utilization of the root crop is limited to a handful of food forms. It is mostly fried or boiled and eaten with a sauce or used to sweeten porridges and maize products such as aboloo (Opare-Obisaw *et al.*, 2000). In Ghana and several other countries, advances have been made to maximize culinary benefits from the crop by developing stable and consumer-acceptable food products to be included in different food systems.

*Corresponding author.
Email: *ctortoe@yahoo.co.uk*
Tel: +233-243241801; Fax: +233-302519096

Recent assessments carried out in developing countries suggest that processing sweet potato roots into flour offers a unique opportunity of presenting the commodity in a more stable form (van Hal, 2000). In this regard different varieties have been processed into flour and used as a raw material in the production of several products, including pastry and bakery products such as bread and cakes (Greene and Bovell-Benjamin, 2004), pasta (Singh *et al.*, 2004), beverages (Wireko-Manu, 2010). Key determinants of the success of sweet potato flour lie in its properties. Therefore, there is the need to know the functional properties of newly released varieties for product development and industrial applications of flour from these sweet potato varieties. The objective of the study was to determine the physicochemical and functional properties of flours from 12 varieties of Ghanaian sweet potatoes *(Ipomoea batatas)*.

Materials and Methods

Twelve improved varieties of sweet potato obtained from demonstration farms of the CSIR-Crops Research Institute, Fumesua, Kumasi were used in this study (Table 1). The sweet potato varieties are represented as OG-*Ogyefo*, SP-*Santom pona*, DA-*Dadanyuie*, OT-*Otoo*, GR-*Ligri*, SAT-*Sauti,* SPA-*Patron*, CFA-*Faara,* OK-*Okumkom,* BO-*Bohye*, HI-*Histarch*, AP-*Apomuden*.

Preparation of sweet potato flour

Sweet potato flour was produced using the method described by Jungchud *et al.* (2003), with slight modification. Matured and freshly harvested sweet potato roots were hand-peeled, washed in potable water and manually cut into slices (2-4mm thick). Subsequently, the slices were dipped in 0.01% sodium metabisulphite solution for 5min to prevent browning. These were then spread thinly on trays and dried at 60ºC for 14h in a mechanical dryer (Apex Dryer, CSIR-FRI, Accra, Ghana). Using a hammer mill, the dried slices were milled into fine powder and passed through a 400 µm sieve. The flour obtained was packaged in HDPE bags, sealed airtight with an impulse sealer (Qlink QNS-3200HI, Nigeria) and stored at room temperature for later use.

Colour

Colour of the samples was determined using a Minolta chroma-meter (CR-310), calibrated with a reference white porcelain (L = 97.63, a = 0.31 and b = 4.63). Reflectance and the colour values were expressed as L^* (whiteness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness). The hue angle, which represents the colour the human eye perceives, was calculated using the formula; Hue (h) = arctan (b^*/a^*) (Di Matteo *et al*., 2004).

Table 1. Characteristics of sweet potato roots

Variety	Status	Colour of the flesh
CFA-Faara	Improved	White
DA-Dadanyuie	Improved	White
OG-Ogyefo	Improved	White
OK-Okumkom	Improved	White
HI-Histarch	Improved	Cream
GR-Ligri	Improved	Pale Yellow
SP-Santom pona	Improved	Light yellow
SAT-Sauti	Improved	Yellow
SPA-Patron	Improved	Dark Yellow
BO-Bohye	Improved	Pale Orange
OT-Otoo	Improved	Light orange
AP-Apomuden	Improved	Reddish (Deep) Orange

Moisture content and water activity

Moisture content was determined by AOAC (2000), while water activity was measured using standard methods with a Rotronic Hygrolab 2 (Rotronic, USA).

pH and total titratable acidity (TTA)

Ten gram (10 g) of flour sample was weighed into a 250 ml beaker and 90 ml of distilled water added and shaken thoroughly. The mixture was left for 30min at room temperature and pH measured in triplicate using a pH meter (Jenway 3330, United Kingdom). Flour suspensions from pH measurement were used for determination of TTA by titrimetry. Approximately, 3 drops of phenolphthalein indicator were added to flour suspension and titrated against 0.1M 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 citric acid.

Water-binding capacity (WBC)

WBC was determined in triplicate on the flours according to the method of described by Afoakwa *et al.* (2012). Two gram of flour was dissolved in 40ml of water in a centrifuge tube and this suspension was agitated for 1h at room temperature on a shaker (Grant OLS 200, England) and centrifuged (Hermle Z 206 A, Germany) for 10 min at 2200 rpm (560g). 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:

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

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

Swelling power and solubility index

Swelling power and solubility index were determined using the method described by Afoakwa *et al.* (2012). Aqueous starch dispersions of 2.5% were put in centrifuge tubes, capped to prevent spillage and heated in a water bath with shaker (GRANT OLS 200, England, United Kingdom) at 85°C for 30min. After heating tubes were cooled to room temperature and centrifuged (Hermle Z 206 A, Germany) at 2200 rpm for 15 min. Precipitated paste was separated from the supernatant and weighed (W_p). The supernatant was evaporated in a hot air oven (Gallenkamp Hotbox oven, England, United Kingdom) at 105°C and the residue weighed (Wr). All determinations were done in duplicates and the Swelling Power (SP) and Solubility index (SI) were respectively calculated as:

$$SP = \frac{wt\ of\ precipitated\ paste\ (Wp)}{wt\ of\ sample\ (Wo)} - wt\ of\ residue\ in\ supernatant\ (Wr)$$

$$SI = \frac{wt\ of\ residue\ in\ supernatant\ (Wr)}{wt\ of\ sample\ (Wo)}\ x\ 100$$

Where W_o is the weight of sample taken.

Starch characterization by RVA

Pasting characteristics was determined on a 14% flour suspension using a Rapid Visco Analyser (RVA) (Newport Scientific, Warriewood, Australia). Total running time per sample was 13min using RVA General Pasting Method (STD1). Viscosity of flour was recorded by Thermocline software as the temperature increased from 50 to 95°C and back to 50°C again. Rotation speed was set to 960 rpm for the first 10sec and then to 160 rpm until the end of the determination.

Statistical analysis

The data obtained from triplicate experiments and their means were analyzed by ANOVA using SPSS 16.0. (SPSS Inc, USA), and the. Duncan Multiple Range Test (DMRT) performed to separate varieties with significantly different ($p < 0.05$) means. Statistical significance was set at a level of 95% confidence interval. Results were reported as means ± standard error.

Results and Discussion

Colour of sweet potato flour

Colour, undoubtedly is an indispensable sensorial attribute for characterizing food and judging its quality. Physical colours of the flours ranged from white, cream, yellow (pale or light) to orange, depending on the variety. Instrumental colour measurements was represented by four colour space values (L^*, a^*, b^* and Hue angle). The 12 sweet potato flours were generally light in colour as reflected in the high L^* values (Table 2). Interestingly, flours from the white varieties did not have the highest L^* values. Whereas AP had the lowest L^* value of 83.6 and GR, which has a yellow flesh, had the highest (89.4). This confirms the assertion by van Hal (2000), that whiteness of sweet potato flour is not necessarily associated with root color, but rather, browning reactions that may occur during drying of sweet potato chips. Similar observation were made by Olatunde *et al.* (2015), when they processed 10 different varieties of sweet potatoes.

Lightness index of the flours showed substantial differences ($p < 0.001$), even though the margin of variation among them was quite narrow. Similarity in lightness existed among OK, SAT, BO and OT varieties. Significant differences ($p < 0.05$) were also noticed for a^* and b^* values as well. Interestingly, a^*, which measures colour along the red green spectrum was highest for AP variety. This is not surprising because of its striking orange colour. The measure of yellowness – blueness (b^*) was positive, and therefore suggests that the flours were yellowish. The orange fleshed varieties (AP, BO and OT) had the highest b^* values, followed by the yellow varieties. However, GR, which incidentally is a yellow variety, had the least b^* value. As noted in previous studies, b^* is a better indicator of color of flours from colored sweet potato varieties The °Hue angle has been described as the colour perceived by the naked eye, and is measured in degrees. This colour index was significantly different for the flours and was highest for BO variety and lowest for AP and the white fleshed varieties. The Hue angles greater than 90° denote a yellowish colour whereas those lower than 90°, as observed in AP variety, suggest a slightly yellow to orange colour.

The colour of sweet potato flour, apart from being affected by browning reactions during processing, may also come from natural pigments in the crop (such as the carotenoids and anthocyanins), which affect the red-yellow index of the flour. These natural

Table 2. Colour of sweet potato flour

Variety	L*	a*	b*	H°
CFA	84.57 ± 0.05^{b}	-1.26 ± 0.02^{d}	10.80 ± 0.01^{g}	96.65 ± 0.08^{e}
DA	85.82 ± 0.07^{c}	-0.91 ± 0.02^{g}	10.66 ± 0.02^{f}	94.86 ± 0.12^{b}
OG	88.56 ± 0.11^{i}	-0.90 ± 0.01^{g}	8.24 ± 0.02^{b}	96.26 ± 0.04^{d}
OK	87.25 ± 0.17^{f}	-0.84 ± 0.02^{i}	9.58 ± 0.03^{d}	94.99 ± 0.12^{b}
HI	86.77 ± 0.10^{e}	-0.86 ± 0.02^{hi}	9.35 ± 0.04^{c}	95.26 ± 0.07^{c}
GR	89.38 ± 0.10^{j}	-0.98 ± 0.02^{f}	7.53 ± 0.04^{a}	97.39 ± 0.16^{f}
SP	86.14 ± 0.14^{d}	-0.90 ± 0.01^{gh}	9.65 ± 0.06^{d}	95.31 ± 0.05^{c}
SAT	87.37 ± 0.06^{fg}	-1.20 ± 0.01^{e}	10.49 ± 0.02^{e}	96.51 ± 0.03^{de}
SPA	88.61 ± 0.10^{i}	-2.37 ± 0.01^{b}	14.35 ± 0.02^{i}	99.38 ± 0.03^{g}
BO	87.69 ± 0.10^{h}	-2.52 ± 0.02^{a}	15.16 ± 0.02^{j}	99.44 ± 0.05^{g}
OT	87.57 ± 0.08^{gh}	-1.47 ± 0.02^{c}	11.01 ± 0.02^{h}	97.60 ± 0.07^{f}
AP	83.64 ± 0.07^{a}	1.22 ± 0.01^{j}	23.92 ± 0.07^{k}	86.71 ± 0.11^{a}

Means within the same column with different superscripts are significantly different ($p<0.05$). *OG-Ogyefo, SP-Santom pona, DA-Dadanyuie, OT-Otoo, GR-Ligri, SAT-Sauti, SPA-Patron, CFA-Faara, OK-Okumkom, BO-Bohye, HI-Histarch, AP-Apomuden.*

Table 3. Chemical properties of sweet potato flour

Variety	Moisture (%)	a_w	pH	TTA (%)
CFA	10.00 ± 0.13^{d}	0.60 ± 0.01^{f}	6.07 ± 0.03^{fg}	0.52 ± 0.01^{de}
DA	9.87 ± 0.02^{d}	0.58 ± 0.00^{e}	5.95 ± 0.01^{cd}	0.70 ± 0.01^{e}
OG	8.54 ± 0.07^{c}	0.55 ± 0.00^{bc}	5.98 ± 0.01^{de}	0.65 ± 0.00^{d}
OK	7.60 ± 0.09^{a}	0.52 ± 0.00^{a}	5.91 ± 0.05^{bc}	0.67 ± 0.00^{de}
HI	8.59 ± 0.03^{c}	0.57 ± 0.01^{de}	6.00 ± 0.05^{e}	0.44 ± 0.01^{a}
GR	8.57 ± 0.09^{c}	0.55 ± 0.01^{c}	6.11 ± 0.01^{g}	0.50 ± 0.01^{b}
SP	8.15 ± 0.07^{b}	0.55 ± 0.02^{c}	6.11 ± 0.02^{g}	0.56 ± 0.04^{c}
SAT	9.90 ± 0.11^{d}	0.60 ± 0.01^{f}	5.77 ± 0.01^{a}	0.67 ± 0.02^{de}
SPA	8.62 ± 0.01^{c}	0.58 ± 0.01^{e}	6.04 ± 0.01^{f}	0.68 ± 0.00^{c}
BO	8.71 ± 0.24^{c}	0.56 ± 0.01^{cd}	5.89 ± 0.01^{b}	0.84 ± 0.01^{g}
OT	8.00 ± 0.00^{b}	0.54 ± 0.01^{bc}	6.21 ± 0.01^{h}	0.67 ± 0.01^{de}
AP	8.06 ± 0.05^{b}	0.53 ± 0.00^{ab}	5.90 ± 0.01^{bc}	0.79 ± 0.00^{f}

Means within the same column with different superscripts are significantly different ($p<0.05$). *OG-Ogyefo, SP-Santom pona, DA-Dadanyuie, OT-Otoo, GR-Ligri, SAT-Sauti, SPA-Patron, CFA-Faara, OK-Okumkom, BO-Bohye, HI-Histarch, AP-Apomuden.*

pigments may also have nutritional and health significance in sweet potato flour (van Hal, 2000).

Moisture content, water activity, pH and total titratable acidity of sweet potato flour

Moisture content of the sweet potato flours varied from 7.6 to 10%, which is below the 15.5% max specified for wheat flour (CAC, 1985). Generally, the water activity (aw) was between 0.5 and 0.6, an indication of shelf-stable product. Differences in moisture and water activity may be due to variety peculiarities. As shown, CFA and SAT varieties, which had relatively higher moisture content, were also similar in their water activities (Table 3). These two parameters are essential to the stability of flours in storage. Products with reduced moisture and water activity generally store longer because of reduced microbial and chemical activity. High amounts of moisture in flours may result in caking, a phenomenon characterized by aggregation of particles into lumps. This may lead to a reduction in flour quality and its functionality (Aguilera *et al*., 1995).

The pH is a sign of acidity or alkalinity, and greatly affects the performance of flours in many food processing applications. The 12 flours were generally slightly acidic and had pH range of 5.8 - 6.2

Table 4. Functional properties of sweet potato flour

Variety	Swelling Power (g/g)	Solubility Index (%)	Water Binding Capacity (%)
CFA	5.00 ± 0.26^{abcde}	7.49 ± 0.13^{c}	95.25 ± 4.15^{bc}
DA	5.28 ± 0.11^{de}	5.60 ± 0.61^{b}	94.70 ± 3.10^{bc}
OG	5.16 ± 0.35^{de}	3.36 ± 0.32^{a}	97.10 ± 2.30^{bc}
OK	4.62 ± 0.35^{ab}	5.71 ± 0.88^{b}	89.50 ± 0.20^{bc}
HI	4.55 ± 0.05^{a}	7.36 ± 0.04^{c}	79.50 ± 1.60^{a}
GR	5.13 ± 0.13^{cde}	5.06 ± 0.09^{b}	94.15 ± 3.25^{bc}
SP	5.39 ± 0.08^{e}	4.52 ± 0.06^{ab}	95.95 ± 3.95^{bc}
SAT	5.08 ± 0.17^{bcde}	4.56 ± 0.84^{ab}	98.10 ± 2.40^{c}
SPA	4.83 ± 0.08^{abcd}	4.61 ± 0.62^{ab}	87.50 ± 5.20^{ab}
BO	5.89 ± 0.07^{f}	4.16 ± 1.83^{ab}	114.55 ± 1.65^{d}
OT	4.65 ± 0.25^{abc}	7.28 ± 0.40^{c}	90.85 ± 2.65^{bc}
AP	5.10 ± 0.20^{bcde}	9.68 ± 0.01^{d}	111.40 ± 1.10^{d}

Means with different superscripts are significantly different ($p<0.005$). *OG-Ogyefo, SP-Santom pona, DA-Dadanyuie, OT-Otoo, GR-Ligri, SAT-Sauti, SPA-Patron, CFA-Faara, OK-Okumkom, BO-Bohye, HI-Histarch, AP-Apomuden*

correspondingly for SAT and OT varieties (Table 3). The pH range is comparable to the range suggested for sweet potato by Mweta (2009) and van Hal (2000), and some were similar to that of wheat flour. Very acidic flours (pH < 4) suggests a considerable extent of fermentation and hence starch breakdown and such acidic flours are particularly not suitable for processing into bakery and pastry products. Total titratable acidity of the sweet potato flours were significantly different ($p < 0.001$) among the 12 varieties and ranged from 0.50 - 0.84% for GR and BO variety, respectively. The TTA is an indicator of freshness in flours.

Swelling power, water solubility index and water binding capacity

Range of values for swelling power (SP), water solubility index (SI) and water binding capacity (WBC) were 4.6 - 5.9g/g, 3.4 - 9.7% and 87.5 - 114.6%, respectively (Table 4). The differences between varieties in respect of these indices were significant ($p < 0.001$).

Similarity in the functional properties were observed among the flours. With the exception of BO, which incidentally had the highest swelling power and water binding capacity, each of the remaining flours had similar swelling power. A similar situation was observed for water solubility index, where the AP variety was considerably higher than the remaining varieties. Although the flours were from the same botanical source, differences in swelling power and water solubility index may be attributed to differences in starch structure and morphology, amylose and amylopectin and the presence of salts, proteins and other components brought about by differences in genetic makeup. The swelling power is classified as a measure of the hydration capacity of starches and is used to provide evidence for associative binding forces within starch granules. The swelling power of the flours obtained were lower than that reported by Srichuwong *et al.* (2005) but compared well with that reported by Ocloo *et al.* (2011) for non-irradiated sweet potato starch. However, the water solubility index was lower, possibly due to the interference of other components present in sweet potato flour as opposed to the starch. In addition to the intermolecular forces, variations in amylose content and granular architecture may also account for differences in swelling power and water solubility index.

The water binding capacity is reflective of protein-water interaction in food systems and is therefore influenced greatly by protein content. The differences observed may be attributed to differences in water binding sites available in the various flours (Wotton and Bamunuarachchi, 1978). The high water binding capacity obtained for BO (114.6%) and AP (111.4%), denotes the possession of lots of water-binding sites by these flours as compared to HI (79.5%), SPA (87.5%) and OK (89.5%). High water binding capacity has also been attributed to loosely associated amylose and amylopectin whereas the association of hydroxyl groups to form hydrogen and covalent bonds between starch chains lowers water binding capacity (Das *et al*., 2010; Hoover and Sosulski, 1986). The water binding capacity of

Table 5. Viscoelastic properties of sweet potato flour

Variety	Peak V (RVU)	Trough (RVU)	Breakdown (RVU)	Fin. viscosity (RVU)	Setback (RVU)	Pasting Temp (°C)
CFA	147.08 ± 0.90^{b}	93.53 ± 1.49^{b}	53.56 ± 1.27^{b}	138.92 ± 0.67^{b}	45.39 ± 0.85^{b}	81.40 ± 0.43^{cde}
DA	207.94 ± 1.63^{e}	121.06 ± 1.21^{d}	86.89 ± 2.76^{e}	189.61 ± 0.92^{d}	68.56 ± 1.49^{c}	79.97 ± 0.06^{b}
OG	288.11 ± 0.71^{h}	178.92 ± 0.43^{h}	109.19 ± 0.54^{g}	296.14 ± 0.83^{l}	117.22 ± 0.64^{i}	81.08 ± 0.53^{cd}
OK	165.00 ± 1.25^{c}	99.53 ± 0.94^{c}	65.47 ± 0.94^{c}	144.67 ± 0.33^{c}	45.14 ± 0.89^{b}	81.55 ± 0.00^{cdef}
HI	300.36 ± 2.62^{j}	152.11 ± 2.65^{f}	148.25 ± 2.53^{j}	228.19 ± 2.63^{f}	76.08 ± 1.40^{d}	79.23 ± 0.03^{a}
GR	304.19 ± 1.67^{k}	179.67 ± 2.03^{h}	124.53 ± 0.63^{i}	268.83 ± 1.02^{i}	89.17 ± 2.63^{g}	82.47 ± 0.08^{g}
SP	213.39 ± 0.17^{i}	139.56 ± 3.21^{e}	73.83 ± 3.10^{d}	218.75 ± 1.80^{e}	79.19 ± 1.48^{e}	81.87 ± 0.51^{efg}
SAT	202.83 ± 1.77^{d}	117.67 ± 0.14^{d}	85.17 ± 1.76^{e}	186.42 ± 2.05^{h}	68.75 ± 2.02^{c}	82.12 ± 0.53^{fg}
SPA	275.75 ± 0.66^{f}	157.67 ± 3.51^{g}	118.08 ± 4.06^{h}	238.44 ± 1.25^{g}	80.78 ± 2.52^{e}	80.97 ± 0.46^{c}
BO	299.72 ± 3.13^{j}	195.36 ± 3.64^{i}	104.36 ± 3.46^{f}	279.94 ± 2.19^{k}	84.58 ± 3.59^{f}	83.73 ± 0.43^{h}
OT	283.22 ± 2.29^{g}	180.03 ± 3.10^{h}	103.19 ± 1.19^{f}	276.86 ± 2.38^{j}	96.83 ± 0.75^{h}	81.62 ± 0.01^{def}
AP	74.81 ± 0.24^{a}	25.92 ± 0.25^{a}	48.89 ± 0.13^{a}	35.75 ± 0.14^{a}	9.83 ± 0.29^{a}	84.05 ± 0.05^{h}

**Means within the same column with different superscripts are significantly different ($p<0.05$). *OG-Ogyefo, SP-Santom pona, DA-Dadanyuie, OT-Otoo, GR-Ligri, SAT-Sauti, SPA-Patron, CFA-Faara, OK-Okumkom, BO-Bohye, HI-Histarch, AP-Apomuden*

the flours correlated positively ($r = 0.721$, $p = 0.008$) with swelling power, similar to that observed in earlier studies by Wang and Seib (1996).

Viscoelastic properties

The performance of flours in food systems is dependent on the cooking behavior of their starches, and this provides useful information during new product development. Indices that depict the behaviour of cooked flours from the 12 sweet potato varieties were studied (Table 5). Pasting curves of slurries from the 12 sweet potatoes varieties were typical of unprocessed starchy products.

The pasting profile of the flours followed the type A viscosity pattern, in which a high pasting peak is followed by rapid and major thinning during cooking (Moorthy, 2002; Jangchud *et al.*, 2003). All the flours showed distinct peaks, an indication that pasting progressed uniformly (Katayama *et al.*, 2004). Although the different flours showed the same kind of profile, variations were observed in the parameters that characterize these profiles (Table 5).

Pasting temperatures were generally significantly different ($p < 0.05$) among the flours but some similarities were observed as well. Apart from DA and HI, which had pasting temperatures of 79.97 and 79.23°C, respectively, all the flours were observed to begin gelatinizing at 81°C or higher. The implication is that these two varieties will be easier to cook, compared to the remaining 10 varieties. The AP had the highest pasting temperature of 84.05°C, and would thus require more energy to cook. Pasting temperatures obtained in this study were slightly higher values than 74 – 78°C as reported by Moorthy (2002). Pasting temperature has been described as the point at which irreversible swelling of starch granules occur, resulting in the formation of a viscous paste. It is indicative of the minimum temperature required to cook starch/flour slurry and the energy costs involved (Sandhu *et al.*, 2005). Differences in this index may result from varying starch granule size among the flours, with larger granules being associated with lower pasting temperature and high swelling properties (Jangchud *et al*., 2003).

Peak viscosity (PV) represents the maximum viscosity attained by the paste during the heating cycle and reflects the ability of starch granules to freely swell (Singh *et al.*, 2004). This ranged from nearly 74 to 304 RVU, with wide variations, indicating significant differences ($p < 0.05$) existing among the different sweet potato flours. Nonetheless, Duncan Multiple Range Test on the viscometry data showed similarity in peak viscosity between flours from BO and HI varieties. The peak viscosity values obtained were higher compared to 103.9-120.0RVU reported by Jangchud *et al*. (2003) for orange and purple flesh sweet potato flour but lower than 381.9-433.4RVU reported by the same authors for orange and purple flesh sweet potato starches.

Breakdown viscosity of the pastes showed a clear breakdown (53.6 – 149.3RVU), which occurred as a result of the implosion of swollen starch granules during cooking. A rise is thereafter noticed due to retrogradation, a phenomenon which is ascribed to re-association of starch molecules during cooling. Breakdown in viscosity of cooked pastes denote their stability to shearing during cooking (Beta and Corke, 2001). The SP and BO had the highest stability ratio (trough/peak viscosity) of 0.65 and are therefore expected to better withstand shear at high temperatures (Sefa-Dedeh and Sackey, 2002), compared to AP which had a remarkably lower stability ratio of 0.35.

Final viscosity ranged between 35.8 and 296.1RVU with each flour from each variety differing significantly ($p < 0.001$) from one another. The final viscosity indicates the ability of starches to form a firm gel or viscous paste and is useful in predicting the texture of food products (Afoakwa *et al*., 2010). Apart from AP, CFA, OK, SAT and DA, the remaining 7 varieties had a final viscosity higher than 200RVU. Setback is used to depict the retrogradation tendency of cooked pastes and this occurs when pastes are cooled. This phenomenon is characterized by gelling and increase in firmness and rigidity of pastes, loss of paste clarity and occurs as a result of the reordering of amylose and a reversible crystallization of amylopectin molecules (Gudmundsson, 1994). Setback was highest in OG and lowest in AP, with pastes from these two varieties showing setback ratios (final viscosity/trough) of 1.66 and 1.38, respectively. This implies that cooked pastes from OG are the most susceptible, whereas AP has the least tendency to retrograde. Differences in setback among the flours were remarkable ($p < 0.001$) and may be ascribed to structural differences in amylopectin molecule, lipids content (Gudmundsson, 1994). However further investigations are needed.

Conclusion

The study has shown that flour from the 12 varieties of Ghanaian sweet potatoes possess good physicochemical and functional properties that makes them applicable in a wide array dietary and industrial purposes. The flours were fairly neutral, with low acidity and their colours closely associated with the type of sweet potato. They showed good water solubility and binding indices as well as remarkable pasting characteristics. Their pasting temperature ranged between 79 and 84°C while peak viscosity and breakdown viscosity varied from 75 – 304 and 48.89-148.25RVU, respectively, an indication that they can cook easily into pastes that are stable to shearing forces at high temperatures.

Acknowledgements

The authors are grateful for sponsorship from the West Africa Agricultural Productivity Programme (WAAPP2A-Ghana) and the Swedish University of Agricultural Sciences, Uppsala, Sweden for financial support.

References

Afoakwa, E. O., Adjonu, R. and Asomaning, J. 2010. Viscoelastic properties and pasting characteristics of fermented maize: Influence of the addition of malted cereals. International Journal of Food Science and Technology 45: 380-386.

Afoakwa, E. O., Budu, A., Asiedu, S Chiwona-Karltun C. and Nyirenda, D. B. 2012. Viscoelastic properties and physico-functional characterization of six high yielding cassava mosaic disease-resistant cassava (*Manihot esculenta* Crantz) genotypes. Journal of Nutrition and Food Sciences 2: 129.

Aguilera, J. M., del Valle, J. M. and Karel, M. 1995. Caking phenomenon in amorphous food powders. Trends in Food Science and Technology 6: 149-155.

AOAC. 2000. Official methods of analysis, 17th ed. Association of Official Analytical Chemists. Washington, DC: AOAC Press.

Beta, T. and Corke, H. 2001. Noodle Quality as related to sorghum starch properties. Cereal Chemistry 78: 417-420.

CAC, 1985. Codex Standard for Wheat Flour: Codex Stan 152-1985. Codex Alimentarius Commission. Italy: CAC Press.

Das, A. B., Singh, G., Singh, S. and Riar, C. S. 2010. Effect of acetylation and dual modification on physico-chemical, rheological and morphological characteristics of sweet potato starch. Carbohydrate Polymers 80: 725-732.

Di Matteo, M., Albanese, D., Attanasio, G. and Cinquanta, L. 2004. Effects of drying temperatures on physicochemical properties of dried and rehydrated chestnuts. Food Chemistry 88(4): 583-590.

Ewell, P. 1993. Sweet potato in Africa: Research priorities to stimulate increased marketing. Paper presented at the International Workshop on Methods of Agricultural Marketing Research, 16-20 March, 1993: New Delhi, India. IARI Campus.

Greene, J. L. and Bovell-Benjamin, A. C. 2004. Macroscopic and sensory evaluation of bread supplemented with Sweet-potato flour. Journal of Food Science 69: 167-173

Gudmundsson, M. 1994. Retrogradation of starch and the role of its components. Thermochimica Acta 246: 329-341.

Hoover, R. and Sosulski, F. 1986. Effect of cross linking on functional properties of legume starches. Starch/Starke 38: 149-155.

Moorthy, S. N. 2002. Physicochemical and functional properties of tropical tuber starches: A review. Starch/Starke 54: 559-592.

Mweta, D. E., Maryke, T. L., Bennet, S. and Saka, D. K. J. 2010. Physicochemical properties of starches from Malawian sweet potato *(Ipomea batatas)* cultivars. Trends in Carbohydrate Research 2(1): 1-12.

Jangchud, K., Phimolsiripol, Y. and Haruthaithanasan,

V. 2003. Physico-chemical properties of sweet potato flour and starch as affected by blanching and processing. Starch/Starke 55: 258-264.

Katayama, K., Tamiya, S. and Ishiguro, K. 2004. Starch properties of new sweet potato lines having low pasting temperature. Starch/Starke 56: 563-569.

Ocloo, F. C. K., Otoo, G., Nkansah, R. M., Mahami, T., Odonkor, S. and Quayson, E. T. 2011. Functional and physicochemical characteristics of starch obtained from gamma-irradiated sweet potato *(Ipomea batatas)*. Journal of Agriculture and Food Technology 1:116 -122

Olatunde, G. O., Henshaw, F. O., Idowu, M. A. and Tomlins, K. 2015. Quality attributes of sweet potato flour as influenced by variety, pretreatment and drying method. Food Science and Nutrition 2015: 1- 13.

Opare-Obisaw, C., Danquah, A. O., Doku, E.V., Boakye, B. B. and Ansah-Kissiedu, D. 2000. Consumer evaluation of five new sweet potato *(Ipomoea batatas)* varieties. Journal of Consumer Studies and Home Economics 24: 61-65.

Rees, D., van Oirschot, Q. E. A., Amour, R., Rwiza, E., Kapinga, R. and Carey, T. 2003. Cultivar variation in keeping quality of sweet potatoes. Postharvest Biology and Technology 28: 313-325.

Sandhu, K. S., Singh, N. and Malhi, N. S. 2005. Physicochemical and thermal properties of starches separate from corn produced from crosses of two germ pools. Food Chemistry 89: 541-548.

Sefa-Dedeh, S. and Sackey, E. K. A. 2002. Starch Structure and some properties of cocoyam *(Xanthosoma sagittifolium* and *Colocasia esculenta*) starch and raphides. Food Chemistry 79: 435-444.

Singh, S., Raina, C. S., Bawa, A. S. and Saxena, D. C. 2004. Sweet potato-based pasta product: optimization of ingredient levels using response surface methodology. International Journal of Food Science and Technology 39: 191-200.

Srichuwong, S. Sunarti, T. C., Mishima, T., Isono, N. and Hisamatsu, M. 2005. Starches from different botanical sources II: Contribution of starch structure to swelling and pasting properties. Carbohydrate Polymers 62: 25-34.

SRID. 2013. Statistical, Research and Information Directorate. Ghana: Ministry of Food and Agriculture.

Teye, E., Amoah, R. S., Abano, E. E., Sam-Amoah, L. K. and Tetteh, J. P. 2011. Comparison of two storage structures for the storage of sweet potato tuberous roots in the coastal savannah zone of Ghana. Journal of Agriculture Food Science and Technology 1: 81-88.

Tomlins, K. I., Ndunguru, G., Rwiza, E. and Westby, A. 2000. Post-harvest handling, transport and quality of sweet potatoes in Tanzania. Journal of Horticulture, Science and Biotechnology 75: 586-590.

van Hal, M. 2000. Quality of sweet potato flour during processing and storage. Food Reviews International 16: 1-37.

Wang, L. and Seib, P. A. 1996. Australian salt-noodle flours and their starches compared to US wheat flours and their starches. Cereal Chemistry 73:167–175.

Woolfe, J. A. 1992. Sweet potato: an untapped food resource, p. 643. Cambridge: Cambridge University Press.

Wotton, M. and Bamunuarachchi, A. 1978. Water binding capacity of commercial produced native and modified starches. Starch/Starke 33: 159–161.

Wireko-Manu, F. D., Ellis, W. O. and Oduro, I. 2010. Production of a non-alcoholic beverage from sweet potato (*Ipomoea batatas* L.). African Journal of Food Science 4: 180-183.