African Journal of Biotechnology Vol. 12(11), pp. 1250-1256, 13 March, 2013
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB12.1666
ISSN 1684–5315 ©2013 Academic Journals

Full Length Research Paper

Effect of varieties on physicochemical and pasting characteristics of water yam flours and starches

M. O. Oke[1]*, S. O. Awonorin[2] and T. S. Workneh[1]

[1]School of Engineering, Bioresource Engineering, University of KwaZulu-Natal, South Africa.
[2]Department of Food Science and Technology, University of Agriculture, Abeokuta, (UNAAB), Ogun State, Nigeria.

Accepted 1 February, 2013

Water yam (*Dioscorea alata*) flour and starch of ten varieties were processed using standard wet-milling procedure prior to the determination of their physico-chemical and pasting properties. The swelling power of the samples was characterized in the category of high restricted-swelling starch (9.21 to 11.03% for flours; 9.49 to 13.80% for starches). This characteristic is desirable for the manufacture of value-added products such as noodles and composite blends with cereals. The pasting temperature (78.05 to 86.13°C, for flours; 80.38 to 86.15°C for starches) and time (4.44 to 5.17 min for flours; 4.53 to 5.17 min for starches) of test varieties indicate higher gelatinization temperature and longer cooking time. Results of analyses of physico-chemical and pasting properties indicated significant differences ($P < 0.05$) among the varieties. All the varieties studied gave the potentials for the manufacture of these value-added products and non-food applications of starch such as in paper and textile industries. Moreover, the results obtained in this study also show that potential exists for selecting nutritionally superior varieties of *D. alata* (TDa 297 and TDa 00/00194 for flour, TDa 297 and TDa 98/01183 for starch) and these varieties could be good sources of diets to its consumers and serve as food security in developing countries.

Key words: Water yam, physico-chemical, pasting, flour, starch.

INTRODUCTION

According to Scott et al. (2000), water yam, greater yam (*Dioscorea alata* L.) is the most widely distributed species of yam, though the total quantity produced is less than that of white yam. Water yam (*D. alata L.*) is grown widely in tropical and subtropical regions of the world. They are plants yielding tubers and contain starch between 70 and 80% of dry matter (Zhang and Oates, 1999; Shang et al., 2007). Root and tuber starches have unique physicochemical properties mostly due to their amylose and amylopectin ratio (Jenkins and Donald, 1995; Yen et al., 2009). Cheetham and Tao (1997) reported that crystallinity decreased with increasing amylose content in maize starches. Swelling power and solubility of the flour provide evidence of non-covalent bonding between molecules within the flour granules at a molecular level; many factors may influence the degree and kind of association. These factors include the ratio of amylose to amylopectin, the characteristics of each fraction in terms of molecular weight/distribution, degree/length of branching and conformation (Massaux et al., 2008).

The viscosity of starch paste is an important physical characteristic that determines its potential use in various foods. Likewise, pasting properties indicate what physical changes may be expected during the processing of starchy foods. The most important aspect of yam starches is the influence of the properties of starch on the texture and rheology or flow characteristics of food yams (Ayernor, 1985; Yen et al., 2009), and is of importance in relation to processing characteristics. Pasting properties of starch have traditionally been studied using the Brabender Amylograph/Viscograph (Walker et al., 1988; Konik et al., 1994). This method can be restrictive because of the large amount of flour or starch required

*Corresponding author. E-mail: okem1@ukzn.ac.za, ola4ade@yahoo.com.

and the long analysis time, limiting application to the later stages of breeding programs as reported for wheat (Panozzo and McCormick, 1993).

Earlier study on some functional properties of yam showed that significant differences exist in viscosities among the yam starches studied. *Dioscorea rotundata* gave the strongest gel and pasting temperature ranging between 76 and 85°C. A high swelling power of *D. alata* starches was also reported and its characteristics were related to the bounding forces in the starch granules (Onwuka and Ihuma, 2007). Knowledge of the physico-chemical and functional properties of yam sp. could be used to predict and interpret their behavior under actual cooking and cooling conditions (Hariprakesh and Bala, 1996). This could also enable one modify the starches if necessary to suit product and processing demands (Agwunobi, 1999; Yen et al., 2009). The processed form, in which yam tubers are consumed or preserved, is flour (Iwuoha, 2004). This product makes it possible to extend the supply of yam through the off-season, thereby reducing storage losses as well as marketing and transportation costs (Coursey and Ferber, 1979). Yam flour specifically, white yam has found increasing use in bakery (Coursey and Ferber, 1979; IITA, 1988; Iwuoha, 2004). The fact that varietal differences in tuber (Kamenam et al., 1987; FAO, 1991; Iwuoha, 2004; Massaux et al., 2008) affect the functional qualities of yam flour cannot be over-emphasized.

This study showed the feasibility of using some *D. alata* varieties (seven improved genotypes and three landraces) in the production of flour and starch. These products will be subsequently analyzed in order to investigate the potential for the manufacture of value-added products such as noodles and composite blends with cereals that is usually produced with wheat flour and in most cases imported to African countries. The variations of such properties for the different yam flours and starches studied could be of significance in the formulation of diets for diabetics and other health conscious individuals and also for use as binders or disintegrants in tablet and granule formulations. However, little or nothing has been done on the effects of variety on physicochemical and pasting characteristics of water yam flour and starch. There is a need for comprehensive investigation so that the factor/variable may be completely evaluated and comparatively accounted for. In view of the foregoing, tuber variety has been chosen as the condition/working variable. Therefore, the objective of this study was to comparatively evaluate the physicochemical and pasting characteristics of flours and starches as functions of water yam tuber variety.

MATERIALS AND METHODS

Ten varieties of *D. alata* (TDa 98/01176; TDa 99/01169; TDa 297; TDa 98/01183; TDa 92-2; TDa 01/00081; TDa 93-36; TDa 98/01174; TDa 00/00104 and TDa 00/00194) were used in all the experiments. The *D. alata* were obtained from experimental plots of the yam breeding programme at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Ten tubers from representative varieties of *D. alata* were selected by simple randomization procedure from bulk of freshly harvested tubers. The tubers were washed and peeled and each cut into four portions longitudinally (from proximal to distal end). The opposite portions from each tuber were selected and pooled together, cut into small pieces (cubes) and thoroughly mixed. The fresh sample was converted to flour and starch for the physicochemical and pasting characteristics. The determinations of physicochemical and pasting properties were carried out in duplicate.

Sample preparation

Flour preparation

The yam samples for flour were peeled, diced into cubes of about 1 cm each and placed in paper bags. All samples were dried in the oven at 60°C for four days. The dried chips were subsequently milled into flour with hammer mill (Brook Crompton, Huddersfield, England) to pass through a mesh of 150 µm screen size. The flour samples were put in zip-lock bags and kept in covered plastic containers at 20°C for analyses.

Starch extraction

Starch extraction was done by the disruption of yam tissue to expose the starch according to the modified method of Walter et al. (2001). Each yam sample for starch extraction was peeled and cleaned of adhering soil particles. The tubers were later washed and grated to produce yam slurry. The grating was intermittently done to prevent the starch from heating up due to heat from grater. The resultant slurry was placed in a muslin cloth and lowered into distilled water (DW) inside a bucket. The cloth was held at the mouth and the contents were continuously squeezed to sieve out the starch into the water. The starch was allowed to settle and the supernatant decanted.

Further stirring of the starch with DW, settling of the starch granules and decantation of the supernatant removed soluble impurities. This process was repeated till the supernatant was as clear as the distilled water. The wet starch was spread out on trays and allowed to dry at 45°C in a cabinet drier till the following day (Akinwande et al., 2004). Final weight of the dried starch was again noted before milling into very fine particle size by a micro mill, and kept in zip-lock bags in closed plastic containers for analyses.

Physicochemical properties

Swelling power and solubility index

The swelling power was gotten using the method of Leach et al. (1959) and 1.0 g of the dried sample was weighed into a 125 ml conical flask. Exactly 15.0 ml of distilled water was added and then shaken on a shaker for 5 min at low speed. The sample was then transferred into a water bath and heated for 40 min at 80°C with constant stirring. The gel formed was then transferred into a pre weighed centrifuge tube and 7.5 ml of distilled water were added. It was then centrifuged at 2200 rpm for 20 min. The supernatant was then carefully decanted into a pre weighed drying can and dried at 100 to 105°C to constant weight. The weight of the gel in the centrifuge tube was also determined.

The swelling power and solubility index was then calculated as:

$$\text{Swelling Power} = \frac{\text{Weight of the wet mass of sediment}}{\text{Weight of sample}} \times 100 \tag{1}$$

$$\text{Water Solubility Index} = \frac{\text{Weight of soluble}}{\text{Weight of sample}} \times 100 \qquad (2)$$

Water binding capacity

Water binding capacity was derived using the modified method of Soni et al. (1985). About 2.5 g of the samples (flours and starches) was suspended in 30 ml distilled water at 30°C in a centrifuge tube, stirred for 30 min intermittently and then centrifuged at 3000 rpm for 10 min. The supernatant was decanted and the weight of the gel formed was recorded. The water binding capacity (WBC) was then calculated as gel weight per gram dry sample:

$$\text{WBC} = \frac{\text{Gram bound water}}{\text{Weight of sample (g)}} \times 100 \qquad (3)$$

Amylose content determination

Amylose content was determined using the method of Juliano (1971) and Hoover and Ratnayake (2002). Approximately, 0.1 g (100 mg) of the samples (flours and starches) was weighed into a 100 ml volumetric flask and 1 ml of 99.7 to 100 % (v/v) ethanol and 9 ml of 1N-sodium hydroxide (NaOH) was carefully added and the mouth of the flask was covered with parafilm or foil and the content was mixed well. The samples were heated for 10 min in a boiling water bath to gelatinize the starch (the timing was started when boiling began). The samples were then removed from the water bath and allowed to cool very well. It was then filled up to the mark with distilled water and shaken well. About 5 ml of the mixture was then pipetted into another 100 ml volumetric flask. Acetic acid (1 N, 1.0 ml) and 2 ml of iodine solution were added, and top to mark with distilled water. Absorbance (A) was then read using spectrophotometer at 620 nm wavelength. The blank contained 1 ml of ethanol, 9 ml of sodium hydroxide, and then boiled and top up to the mark with distilled water. 5 ml was then pipetted into a 100 ml volumetric flask. Approximately, 1 ml of 1N acetic acid and 2 ml of iodine solution were added and then filled up to the mark, this was used to standardize the spectrophotometer at 620 nm. The amylose content was calculated as:

$$\text{Amylose content (\%)} = (3.06)(A)(20)$$

$$= 61.20\ (A)$$

Where, A = Absorbance value.

$$\text{Amylopectin (\%)} = 100 - \text{Amylose content}$$

Pasting properties

Pasting characteristics were determined with a Rapid Visco Analyser (RVA Super 3, Newport Scientific Pty. Ltd, Australia). A 3 g sample (flour and starch) was dissolved in 25 ml of water in a sample canister. The sample was thoroughly mixed and fitted into the RVA as recommended (Newport Scientific, 1998). The slurry was heated from 50 to 95°C with a holding time of 2 min followed by cooling to 50°C with another 2 min holding time. The 12 min profile was used and the rate of heating and cooling was at a constant rate of 11.25°C/min. Corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature from the pasting profile were read from a computer connected to the RVA.

Statistical analysis

Samples were randomized and duplicated in all the analyses above and the general linear model procedure (GLM) of SAS Version 9.1 (SAS Institute Inc., 2003) was used to evaluate duplicated results and significant differences were reported at 95% confidence level. Means were separated using LSD test at 5% level of significance as described by Steel and Torrie (1980).

RESULTS

Physicochemical properties of flours and starches of *D. alata* varieties

The physicochemical properties of flours and starches of water yam (*D. alata*) varieties are shown in Tables 1 and 2, respectively. The amylose and amylopectin contents of flours from *D. alata* in this study ranged from 24.29 (TDa 98/01176) to 35.09% (TDa 00/00194) and 64.91 (TDa 00/00194) to 75.71% (TDa 98/01176) (Table 1), respectively, while that of the starches ranged from 27.47 (TDa 297) to 41.90% (TDa 93-36) and 58.10 (TDa 93-36) to 72.53% (TDa 297) (Table 2), respectively.

The swelling power of flours and starches from water yam varieties at 95°C are also shown in Tables 1 and 2, respectively. The values for flours ranged from 9.21 (TDa 297) to 11.03% (TDa 99/01169) (Table 1), while that of the starches ranged from 9.49 (TDa 98/01183) to 13.80% (TDa 00/00194) (Table 2). The values for their water solubility index and water binding capacity of the flours also ranged from 6.83 (TDa 00/00194) to 20.47% (TDa 99/01169) and 96.16 (TDa 297) to 138.92% (TDa 01/00081) (Table 1), respectively, while that of the starches ranged from 2.98 (TDa 99/01169) to 6.68% (TDa 92-2) and 77.70 (TDa 297) to 112.91% (TDa 98/01174) (Table 2), respectively.

Pasting properties of flours and starches of *D. alata* varieties

The pasting properties of flours and starches of the *D. alata* varieties are presented in Tables 3 and 4, respectively. The peak viscosity of the flours ranged from 168.46 RVU (TDa 297) to 317.68 RVU (TDa 98/01176) (Table 3), while that of starches ranged from 272.38 (TDa 98/01183) to 400.79 RVU (TDa 00/00104) (Table 4). The final viscosity of the flour ranged from 56.12 (TDa 98/01174) to 354.20 RVU (TDa 98/01176) (Table 3), while that of starches ranged from 274.80 (TDa 297) to 503.96 RVU (TDa 01/00081) (Table 4). The pasting temperature (gelatinization temperature) at which the peak viscosity occurred in the *D. alata* flours and starches ranged from 78.05 (TDa 00/00104) to 86.13°C (TDa 93-36); 80.38 (TDa 00/00104) to 86.15°C (TDa 98/01174), respectively. The pasting time at which the peak viscosity occurred ranged from 4.44 (TDa 00/00104) to 5.17 min (TDa 98/01176) for flours and 4.53 (TDa 00/00104) to 5.17 min (TDa 93-36) for starches.

Table 1. Physicochemical properties of flours from different varieties of water yam.

Variety	Amylose (%)	Amylopectin (%)	WSI (%)	SP (%)	WBC (%)
TDa 98/01176	24.29^{c}	75.71^{a}	15.45^{b}	9.93^{abc}	131.16^{a}
TDa 99/01169	26.14^{bc}	73.86^{bc}	20.47^{a}	11.03^{a}	121.86^{ab}
TDa 297	27.11^{bc}	72.89^{bc}	8.26^{c}	9.21^{c}	96.16^{b}
TDa 98/01183	27.20^{bc}	72.80^{bc}	13.93^{b}	10.28^{abc}	123.65^{ab}
TDa 92-2	33.87^{a}	66.13^{c}	15.17^{b}	10.52^{ab}	131.91^{a}
TDa 01/00081	33.93^{a}	66.08^{c}	13.29^{b}	10.44^{abc}	138.92^{a}
TDa 93-36	28.30^{bc}	71.70^{bc}	13.24^{b}	9.97^{abc}	126.35^{ab}
TDa 98/01174	29.05^{b}	70.95^{b}	15.77^{b}	9.73^{bc}	133.57^{a}
TDa 00/00104	29.49^{b}	70.51^{b}	9.02^{c}	9.72^{bc}	124.73^{ab}
TDa 00/00194	35.09^{a}	64.91^{c}	6.83^{c}	9.32^{bc}	121.54^{ab}
LSD	0.8286	0.8286	1.8624	0.2179	21.3660

Mean values (n = 2) with different superscripts in the same column are significantly different at $P < 0.05$. **WSI,** Water solubility index; **SP,** swelling power; **WBC,** water binding capacity.

Table 2. Physicochemical properties of starches from different varieties of water yam.

Variety	Amylose (%)	Amylopectin (%)	WSI (%)	SP (%)	WBC (%)
TDa 98/01176	38.74^{abc}	61.26^{abc}	4.76^{ab}	11.54^{b}	81.79^{cde}
TDa 99/01169	40.85^{a}	59.15^{d}	2.98^{b}	11.58^{b}	92.19^{bc}
TDa 297	27.47^{d}	72.53^{a}	6.17^{ab}	13.39^{a}	77.70^{e}
TDa 98/01183	34.54^{bc}	65.47^{ab}	6.36^{ab}	9.49^{d}	105.51^{a}
TDa 92-2	40.27^{ab}	59.73^{bc}	6.68^{a}	12.92^{a}	80.10^{de}
TDa 01/00081	34.98^{bc}	65.02^{ab}	5.32^{ab}	11.57^{b}	83.75^{bcde}
TDa 93-36	41.90^{a}	58.10^{d}	5.54^{ab}	11.23^{bc}	90.59^{bcd}
TDa 98/01174	39.24^{abc}	60.76^{abc}	6.28^{ab}	10.47^{c}	112.91^{a}
TDa 00/00104	33.93^{c}	66.08^{b}	5.26^{ab}	13.53^{a}	94.42^{b}
TDa 00/00194	38.88^{abc}	61.12^{abc}	6.23^{ab}	13.80^{a}	91.37^{bc}
LSD	0.2624	0.2624	2.9126	0.3215	27.631

Mean values (n = 2) with different superscripts in the same column are significantly different at $P < 0.05$. **WSI,** Water solubility index; **SP,** swelling power; **WBC,** water binding capacity.

Table 3. Pasting properties of flours from different varieties of water yam.

Variety	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	FinalVisc (RVU)	Setback (RVU)	Peak time (Min)	Pasting temperature (°C)
TDa 98/01176	317.68^{a}	284.76^{a}	32.92^{h}	354.20^{a}	74.50^{b}	5.17^{a}	86.05^{a}
TDa 99/01169	178.26^{h}	143.45^{d}	34.81^{h}	180.34^{e}	34.33^{ef}	4.90^{ab}	85.70^{ab}
TDa 297	168.46^{i}	103.08^{g}	65.37^{e}	133.14^{g}	27.92^{ef}	4.84^{abc}	84.90^{abc}
TDa 98/01183	282.61^{b}	154.15^{c}	128.46^{c}	302.43^{b}	149.17^{a}	4.65^{bcd}	83.63^{bc}
TDa 92-2	179.50^{h}	126.86^{e}	52.63^{f}	159.12^{f}	32.75^{ef}	4.74^{bcd}	85.18^{ab}
TDa 01/00081	187.23^{g}	154.16^{c}	33.07^{h}	195.55^{d}	42.25^{de}	4.97^{ab}	84.08^{abc}
TDa 93-36	251.69^{d}	207.55^{b}	44.14^{g}	260.37^{c}	54.09^{cd}	5.14^{a}	86.13^{a}
TDa 98/01174	220.08^{e}	36.07^{i}	184.00^{a}	56.12^{h}	20.63^{f}	4.47^{cd}	81.25^{d}
TDa 00/00104	257.52^{c}	122.15^{f}	135.37^{b}	183.88^{e}	62.09^{bc}	4.44^{d}	78.05^{e}
TDa 00/00194	204.81^{f}	95.91^{h}	108.90^{d}	127.55^{g}	31.44^{ef}	4.72^{bcd}	82.67^{cd}
LSD	3.1551	2.6249	5.5472	6.1629	7.5695	0.2824	1.5606

Mean values (n = 2) with different superscripts in the same column are significantly different at $P < 0.05$.

DISCUSSION

Physicochemical properties of flours and starches of *D. alata* varieties

There were significant differences ($P < 0.05$) in amylose content among the ten varieties. The amylose portion of the starch affects its swelling and hot-paste viscosities. Shimelis and Rakshit (2005) stated that as the amylose content increases, the swelling tends to be restricted and the hot paste viscosity stabilizes. Moreover, high amylose contents are desired in starches that are to be used for the manufacture of extrudates (Oluwole, 2008; Chevanan et al., 2008).

The amylopectin confers tighter structure that should normally present less cohesive effect in D. *alata*. Hence, flours of *D*. *alata* should show loose structure and less binding capacities especially when compared with other species of yam like *D*. *rotundata* (Onwuka and Ihuma, 2007). The functional properties such as starch and amylopectin contents are lower when compared with other species of yam (*D. rotundata*) as reported by Onwuka and Ihuma (2007). This obviously explains why nutritionists recommend the use of more *D. alata* in dietherapy of diabetic patients than *D. rotundata* as *D. alata* presents itself as a more tolerable energy source (Okonkwo, 1985; Shang et al., 2007).

The low value of solubility and swelling power of flour and starch extracted from water yam might be due to the protein-amylose complex formation. According to Pomeranz (1991), formation of protein-amylose complex in native starches and flours may be the cause of a decrease in swelling power. Thus, swelling power and solubility patterns of starches have been used to provide evidence for associative binding force within the granules (Leach et al., 1959). When an aqueous suspension of starch granules is heated, these structures are hydrated and swelling takes place. The high value of water binding capacity could be attributed to the loose association of starch polymer, amylose and amylopectin in the native granules (Biliaderis et al., 1993; Shimelis et al., 2006).

According to Shimelis et al. (2006), starches have been classified as high swelling, moderate swelling, restricted swelling or highly restricted swelling. High-swelling starches have swelling power of approximately 30 or higher at 95°C. Their granules swell enormously and the internal bonds become fragile towards shear when the starch is cooked in water. Restricted-swelling starches have swelling power in the range of 16 to 20 at 95°C. The cross-linkages in their granules reduce swelling and stabilize them against shearing during cooking in water (Galvez and Resurreccion, 1993; Massaux et al., 2008). The low value of swelling power obtained in this study was characterized in the category of high restricted-swelling starch (9.21 to 11.03% for flours; 9.49 to 13.80% for starches). This characteristic is desirable for the manufacture of value-added products such as noodles and composite blends with cereals (Biliaderis et al., 1993; Shimelis et al., 2006). All the varieties studied gave the potentials for the manufacture of these value-added products. Moreover, the results obtained in this study also show that the potential exists for selecting nutritionally superior varieties of *D. alata* (TDa 297 and TDa 00/00194 for flour, TDa 297 and TDa 98/01183 for starch) and these varieties could be good sources of nutrients to its consumers and serve as food security in developing countries.

Pasting properties of flours and starches of *D. alata* varieties

Several changes normally occur upon heating a starch-water system, including enormous swelling, increased viscosity, translucency and solubility, and loss of anisotropy (birefringence) (Shimelis et al., 2006; Ikegwu et al., 2010). These changes are generally defined as gelatinization. The gelatinization temperature range of the *D. alata* flours and starches were 78.05 to 86.13°C and 80.38 to 86.15°C, respectively. The gelatinization temperature obtained was considerably higher than for wheat starch (55.6 to 63.0°C) according to Lineback and Ke (1975). The high initial gelatinization temperature of TDa 297 flour indicates that the granules were slow in swelling (Tables 1 and 2). The temperature is one of the pasting properties which provide an indication of the minimum temperature required for sample cooking, energy costs involved and other components stability. The higher pasting temperature (78.05 to 86.13°C, for flours; 80.38 to 86.15°C for starches) and time (4.44 to 5.17 min for flours; 4.53 to 5.17 min for starches) of test varieties indicate higher gelatinization temperature and longer cooking time. However, for technical and economic reasons, starches/flours with lower pasting time and temperature may be more preferred when all other properties are equal (Iwuoha, 2004; Baah et al., 2009).

Gelatinization and pasting of starch/flour are of importance to the food industry in particular because they influence the texture, stability and digestibility of starchy foods and, thus, determine the application and use of flour/starch in various food products. The peak viscosity also indicates the water binding capacity of starch. Final viscosity is used to define the particular quality of starch and indicate the stability of the cooked paste when in actual use; it also indicates the ability to form a various paste or gel after cooling. Low stability of starch paste is commonly accompanied by high value of breakdown (Moorthy, 2002; Mahasukhonthachat et al., 2010).

Rapid Visco Analyzer (RVA) results shown in Tables 3 and 4 indicate that starch and flour from the water yam samples had distinct pasting properties as compared to each other. Starch from TDa 01/00081 had higher final viscosity (503.96 RVU) as compared to other flours and

Table 4. Pasting properties of starches from different varieties of water yam.

Variety	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	FinalVisc (RVU)	Setback (RVU)	Peak time (min)	Pasting temperature (°C)
TDa 98/01176	364.00^{b}	186.04^{cd}	177.96^{a}	301.13^{c}	115.08^{b}	4.60^{c}	83.75^{bc}
TDa 99/01169	306.75^{def}	166.30^{d}	140.46^{abc}	307.63^{bc}	141.33^{ab}	4.80^{bc}	83.33^{bc}
TDa 297	283.63^{f}	166.96^{d}	116.67^{abcd}	274.80^{c}	107.84^{b}	4.63^{c}	84.45^{abc}
TDa 98/01183	272.38^{f}	183.75^{cd}	88.63^{cd}	300.13^{c}	116.38^{b}	4.84^{abc}	84.33^{abc}
TDa 92-2	344.92^{bc}	181.34^{cd}	163.59^{ab}	285.83^{c}	104.50^{b}	4.60^{c}	83.53^{bc}
TDa 01/00081	354.25^{bc}	299.80^{a}	54.46^{d}	503.96^{a}	204.17^{a}	5.10^{ab}	82.43^{cd}
TDa 93-36	326.96^{cde}	212.79^{bcd}	114.17^{abcd}	312.46^{bc}	99.67^{b}	5.17^{a}	85.03^{ab}
TDa 98/01174	301.79^{ef}	190.63^{cd}	111.17^{bcd}	320.46^{bc}	129.84^{b}	5.10^{ab}	86.15^{a}
TDa 00/00104	400.79^{a}	234.13^{bc}	166.67^{ab}	326.25^{bc}	92.13^{b}	4.53^{c}	80.38^{d}
TDa 00/00194	340.62^{bcd}	256.29^{ab}	84.32^{cd}	408.21^{ab}	151.92^{ab}	5.14^{ab}	83.73^{bc}
LSD	1.5848	0.7636	1.9747	4.0334	4.3608	0.3807	1.1621

Mean values (n = 2) with different superscripts in the same column are significantly different at $P < 0.05$.

starches. TDa 00/00104 flour and starch that had the lowest pasting temperature and time could have more products development potentials than flours and starches from other varieties. Classification of viscosity pattern is important to categorize the starch for end product utilization. According to the viscosity pattern taxonomy of “thick-boiling” starches of Shimelis and Rakshit (2005), the swelling power of 9.21 (TDa 297) to 11.03% (TDa 99/01169) for flours and 9.49 (TDa 98/01183) to 13.80% (TDa 00/00194) for starches obtained in this study classified the samples as highly restricted-swelling starchy foods. The cross-linkages in their granules reduced swelling and stabilized them against shearing during cooking in water. A restricted type of swelling is mostly desired of the starch extracts for the manufacture of value added products, such as noodles. Composite blends with cereals importantly require that the starch granules swell sufficiently and remain intact and stable against shearing during thermal processing (Galvez and Resurreccion, 1993; Massaux et al., 2008). The factors which influence this property may include the size and shape of the starch granules, ionic charge on the starch, type and degree of crystallinity within the granules, presence or absence of fat and protein and, perhaps, molecular size and degree of branching of the starch fractions (Shimelis and Rakshit, 2005). In all, there were significant ($P < 0.05$) differences among the *D. alata* varieties in all the pasting characteristics (Tables 3 and 4).

Conclusion

The swelling power of flour and starch from varieties studied were in the group of highly restricted-swelling starches. This characteristic is desirable for starch extracts to be used for the manufacture of value-added products such as noodles and composite blends with cereals. The pasting characteristics of the flour and starch from different varieties of water yam varied significantly. The decrease in paste viscosities of water yam starch as compared to flour obtained in this study are attributed to the interaction of starch with protein, fat, etc, which depend on the varietal differences and play an important role in the pasting properties of starch.

Overall, the pasting and physicochemical properties obtained indicate that flour and starch have useful technological properties for many applications. It can be used in the food processing industry and non-food applications of starch such as in paper and textile industries. The data showed that the water yam flour and starch can be used as a functional ingredient in food systems. With the high consumption of yam, particularly in Africa, and the appreciable physicochemical properties in the varieties, *D. alata* could be an important contributor to their Recommended Daily Allowance (RDA).

All the varieties studied gave the potentials for the manufacture of these value-added products. Moreover, the results obtained in this study also showed that potential exists for selecting nutritionally superior varieties of *D. alata* (TDa 297 and TDa 00/00194 for flour, TDa 297 and TDa 98/01183 for starch) and these varieties could be good sources of nutrients to its consumers and serve as food security in developing countries. They could also be very useful in nutritional applications and diet formulations. This research revealed that the physicochemical as well as the pasting properties of water yam (*D. alata*) flours and starches presented make them to be considered as excellent resource with possible applications in many food processing.

REFERENCES

Agwunobi LN (1999). *Dioscorea alata* (water yam) as a replacement for maize in diets for laying hues. Trop. Anim. Health Prod. 31:391-396.

Akinwande BA, Adeyemi IA, Akande EO, Ogundipe OD (2004). Effect of substituting flour with yam starch and yam flour on pasting property of composite flour and sensory quality of noodle. NIFST Proceeding of the 28th Annual Conference, Ibadan. pp. 257-258.

Ayernor GS (1985). The yam (*Dioscorea*) Starches. In advances in yam research. 1st Ed. Godson Osuji. Anambra State University of Technology Publishers Nigeria. pp. 79-88.

Baah FD, Maziya-Dixon B, Asiedu R, Oduro I, Ellis WO (2009). Nutritional and biochemical composition of *D.alata* (*Dioscorea* spp.) tubers. J. Food Agric. Environ. 7(2):373-378.

Biliaderis CG, Tonogai JR, Perez CM, Juliano BO (1993). Thermo-physical properties of milled rice starch as influenced by variety and parboiling method. Cereal Chem. 70:512-516.

Cheetham NWH, Tao LP (1997*).* The effects of amylose content on the molecular size of amylose, and on the distribution of amylopectin chain length in maize starches. Carbohydr. Polym. 33:251-261.

Chevanan N, Rosentrater KA, Muthukumarappan K (2008). Effects of processing conditions on feed ingredients containing DDGS in single screw extrusion. Food Bioprocess Technol. pp 1-10.

Coursey DG (1976). The origins and domestication of yams in Africa. In: Origins of African plant domestication. J.R. Harlan, J.M.J. de Wet and A.B.L. Stenler, (eds.) Mouton, The Hague. pp 3383-403.

Coursey DG, Ferber CEM (1979). The processing of yams. In D. L. Pluckett (Ed.), Small-scale processing and storage of tropical root crops. Westview Press, Boulder, Colorado. pp. 189-212.

FAO (1991). Yam (*Dioscorea* spp) processing. In: Post-harvest and processing technologies of African staple foods: a technical compendium. FAO Agric. Services Bulletin 89. Food and Agricultural Organization (FAO), Rome, pp. 225-235.

Galvez FCF, Resurreccion AVA (1993). The effects of decortication and method of extraction on the physical and chemical properties of starch from mung bean (Vigna radiate (L.) wilczec). J Food Process. Preserv. 17:93-107.

Hariprakesh CS, Bala N (1996). Changes in carbohydrate constituents in yam (Dioscorea) tubers during dormancy and sprouting. J. Agric. Food Chem. 44:3066-3069

Hoover R, Ratnayake WS (2002). Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada. Food Chem. 78:489-498.

IITA (1988). Annual Report and Research Highlights, 1987/88. Ibadan, Nigeria: International institute for Tropical Agriculture (IITA).

Ikegwu, O.J., Okechukwu, P.E. and Ekumankana, E.O. (2010). Physico-chemical and pasting characteristics of flour and starch from achi *Brachystegia eurycoma* seed. J. Food Technol. 8(2):58-66.

Iwuoha CI (2004). Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. Food Chem. 85:541-551

Jenkins PJ, Donald AM (1995). The influence of amylose on starch granule structure. Int. J. Biol. Macromol. 17:315-321.

Juliano BO (1971). A simplified assay for milled rice amylose. Cereal Sci. Today 16:334-340.

Kamenam A, Beuchat LR, Chinnan MS, Heaton EK (1987). Composition and physico-chemical properties of yam (*Dioscorea* species) flour prepared using different processes. J. Food Process. Preserv. 11:299-308.

Konik CM, Mikkelsen LM, Moss R, Gore PJ (1994). Relationships between physical starch properties and yellow alkaline noodles quality. Starch/Sta¨ rke, 46:292-299.

Leach HW, McCowen LD, Schoch TJ (1959). Structure of the starch granule I. Swelling and solubility patterns of various starches. Cereal Chem. 36:534-543.

Lineback DR, Ke CH (1975). Starches and low-molecular -weight carbohydrates from chick pea and horse bean flours. Cereal Chem. 52:334-347.

Mahasukhonthachat K, Sopade PA, Gidley MJ (2010). Kinetics of starch digestion in sorghum as affected by particle size. J. Food Eng. 96:18-28.

Massaux C, Sindic M, Lenartz J, Sinnaeve G, Bodson B, Falisse A (2008). Variations in physicochemical and functional properties of starches extracted from European soft wheat *Triticum aestivum* L.): The importance to preserve the varietal identity. Carbohydr. Polym. 71:32-41.

Moorthy SN (2002). Physicochemical and functional properties of tropical tuber starches. Starch/Stärke 54:559-592.

Newport Scientific (1998). Applications Manual for the Rapid ViscoTM Analyzer Using Thermocline for Windows. Newport Scientific Pty Ltd., Warriewood, Australia, pp. 2-26.

Okonkwo SNC (1985). The botany of the yam plant and its exploitation in enhanced productivity of the crops. In G. Osuji (Ed.), Advances in yam research; the biochemistry and technology of the yam tuber. Enugu, Nigeria: Biochemical Soc. Nigeria and ASUT. pp. 3-29.

Oluwole OB (2008). Effect of thermo extrusion cooking on physicochemical, textural and sensory qualities of yam (*Dioscorea rotundata*) and bambara groundnut (*Voandezeia subterranean L. Thou*) blends. Unpublished Ph.D thesis, UNAAB, Abeokuta, Nigeria. pp. 117-213.

Onwuka GI, Ihuma C (2007). Physicochemical composition and product behaviour of flour and chips from two yam sp. (*Dioscorea rotundata* and *Dioscorea alata*). Res. J. Appl. Sci. 2(1):35-38.

Panozzo JF, McCormick KM (1993). The Rapid Visco-Analyzer as a method of testing for noodle quality in a wheat breeding program. J. Cereal Sci. 17:25-32.

Pomeranz Y (1991). Functional properties of food components, 2nd Ed. Academic Press, New York. pp 27-28.

SAS Institute Inc. (2003). SAS® 9.1 Qualification Tools User's Guide. SAS Institute Inc., Cary, NC.

Scott GJ, Rosegrant MW, Ringler C (2000). Roots and Tubers for the 21st Century Trends, Projections, and Policy Options Food, Agriculture, and the Environment Discussion Paper 31, International Food Policy Research Institute. 2033 K Street, N.W., Washington, DC 20006-1002 USA.

Shang H-F, Cheng H-C, Liang H-J, Liu H-Y, Liu S-Y, Hou W-C. (2007). Immunostimulatory activities of yam tuber mucilages. Bot. Stud. 48(1):63-70.

Shimelis AE Meaza M, Rakshit S (2006). Physico-chemical Properties, Pasting Behavior and Functional Characteristics of Flours and Starches from Improved Bean (*Phaseolus vulgaris* L.) Varieties Grown in East Africa. Agricultural Engineering International: the CIGR Ejournal. Manuscript FP 05 015. 8:18-36

Shimelis AE, Rakshit SK (2005). Proximate composition and physico-chemical properties of improved haricot bean (Phaseolus vulgaris L.) varieties grown in Ethiopia. J. Food Sci. Technol (LWT), 38:331-338.

Soni PL, Sharma HW, Dobhal SS, Bisen HL, Savastva H, Gharra MW (1985). The Starch of Discorea ballophyll and Amorphophalius companulalus Starch/starke 37:6-9.

Steel RGD, Torrie JH (1980). Principles and Procedures of statistic, A biometric approach. Second edition. McGraw-Hill Book Coy Inc. New York.

Walker CE, Ross AS, Wrigley CW, McMaster GJ (1988). Accelerated characterization of starch-paste viscosity and set-back with the Rapid Visco-Analyzer. Cereal Foods World 33:491-499

Walter WM, Truong VD, Wiesenborn DP, Carvajal P (2001). Rheological and Physicochemical properties of starches from Moist and Dry-type Sweet potatoes. J. Agric. Food Chem. 48:2937-2942.

Yen A, Tzu-Yin C, George CC (2009). Effect of water content and mucilage on physico-chemical characteristics of Yam (*Discorea alata* Purpurea) starch. J. Food Eng. 95:106-114

Zhang T, Oates CG (1999). Relationship between amylase degradation and physicochemical properties of sweet potato starches. Food Chem. 65:157-163.