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Physicochemical and bioactive properties of selected white yam (*Dioscorea rotundata*) varieties adapted to riverine areas of Nigeria

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Yam (*Dioscorea spp.*) is a major food of cultural, economic and nutritional importance in Nigeria and throughout West Africa. In this sub-region, white yam (*Dioscorea rotundata*) is the most dominant and important species. This study is aimed at characterizing high yielding yam varieties of this species adapted to riverine areas and forest zones of Nigeria for physical and chemical characteristics. Eleven yam varieties collected from local farmers in the South-southern part of Nigeria were evaluated for their physicochemical characteristics, bioactive compounds (vitamin C, phytic acid and tannin), functional and pasting properties. Results indicated that there were significant varietal differences (P<0.05) among the parameters evaluated. The moisture contents of the investigated varieties ranged from 59.5 to 68.8%, ash content ranged from 1.39 to 2.93%, protein content from 1.96 to 4.90%, fat content from 0.356 to 3.39%, total free sugars from 1.05 to 7.02% and total starch from 33.9 to 75.7%. The bioactive content results show that vitamin C content ranged from 5.64 mg/100 g to 6.99 mg/100 g, phytate from 1.12 to 2.37% and tannin from 0.359 to 1.18 mg/g. The pasting properties results show that peak viscosity ranged from 215 to 470 RVU, trough viscosity from 198 to 385 RVU, breakdown viscosity from 8.71 to 84.5 RVU, final viscosity from 278 to 571 RVU, setback viscosity from 66.2 to 204 RVU; peak time ranged from 4.97 to 7.0 min and the pasting temperature from 61.7 to 62.6°C. This study shows that the physical and chemical characteristics of these high yield yam varieties were similar to those reported for most yam varieties in other parts of Nigeria and has a great potential as source of bioactive compounds and protein.

Key words: Yam, *Dioscorea rotundata,* riverine areas, varieties.

INTRODUCTION

Globally, yam is grown in many tropical regions but the main production centre is the savannah region of West Africa, where more than 90% of the crop is grown (Sanusi and Salimonu, 2006; IITA, 2009), with Nigeria

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being the main producer followed by Ghana and Cote d'Ivoire (FAO, 2008). Nigeria produces 60% of the world's yam, annually producing an average of 31 million metric tons (Bergh et al., 2012), although Food and Agriculture Organisation (FAO) estimates showed the annual production to be above 37 million metric tons (FAOSTAT, 2013).

Yam (*Dioscorea* spp.) are widely grown in West Africa (Coursey and Haynes, 1970; Waitt, 1963), they are an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa. In Nigeria, yam has had the second highest production level of any food crop after cassava (Bergh et al., 2012). According to Food and Agriculture Organisation (FAO) estimates, there has been steady rise of 12.6% in domestic consumption of yam between 1990 and 2009 (FAOSTAT, 2013). In addition to the food and market values of yams, they play a major role in socio-cultural life of smallholder households, such as the celebrated New Yam Festival and also the presentation of yams as gifts during marriage ceremonies (Opara, 2003; IITA, 2009).

Yams are grown in the coastal region in rain forests, wood savanna and southern savanna habitats. Common species of yam include *Dioscorea rotundata* (White yam), *Dioscorea cayenensis* (Yellow yam), *Dioscorea alata* (Water yam), *Dioscorea bulbifera* (Potato yam), *Dioscorea dumentorum* (Bitter yam), *Dioscorea esculenta* (Lesser yam), *Dioscorea opposita* (Chinese yam) and *Dioscorea trifida* (Cush-cush yam) (Opara, 1999). However, *D. rotundata* is the most important species particularly in the dominant yam production zone in West and Central Africa (IITA, 2009). Yam is composed mainly of starch (75-84% of the dry weight) with small amounts of proteins, lipids and most vitamins and is very rich in minerals (Lasztity et al., 1998), and low in sodium and saturated fat content (Bergh et al., 2012). Yam's richness in carbohydrate especially starch consequently has a multiplicity of end use. Yam, sweet in flavour, is consumed as boiled yam (as cooked vegetable) or fufu or fried in oil and then consumed. It is often pounded into a thick paste after boiling and is consumed with soup. It is also processed into flour for use in the preparation of the paste. Its use as an industrial starch has also been established as the quality of some of the species is able to provide as much starch as in cereals (Izekor and Olumese, 2010).

The average crude protein content of seven yam cultivars was 7.4%, which was higher than those reported for other tropical roots, and the protein from yam also showed a better amino acid balance for human nutrition (Baquar and Oke, 1976; Bradbury, 1988; Marcus et al., 1998). Modern researches have shown that yam extracts can reduce blood sugar (Hikino et al., 1986; Undie and Akubue, 1986) and blood lipid (Araghiniknam et al., 1996), inhibit microbe activity (Hu et al., 1996, 1999; Kelmanson et al., 2000) and show antioxidative activity (Farombi et al., 2000). Yams also have pharmaceutical usage as they contain a steroid sapogenin compound called diosgenin, which can be extracted and used as base for drugs such as cortisone and hormonal drugs (Opara, 2003). There is little information in the literature on the physical and chemical properties of the high yield yams from riverine areas of Nigeria. The main objective of this study was to characterize the high yielding yam varieties (*D. rotundata*) adapted to riverine areas and forest zones of Nigeria for physical and chemical characteristics.

MATERIALS AND METHODS

Yam tubers and sample preparation

Fresh eleven (11) white yam varieties (*D. rotundata)* designated as high yielding were collected from local farmers in the South-Southern part of Nigeria. The yam samples were thoroughly washed, peeled, oven dried at 60°C. All the dried samples were milled to 0.50 mm sieve size with Perten Laboratory Hammer Mill 3102 for further laboratory analysis.

Moisture content determination

Five grams of sample was weighed into known weight of Petri-dish. The weighed sample was put into the pre-set oven (Fisher Scientific Isotemp^{R} Oven model 655F) at 110°C for 3 h. The sample was removed and cooled in a dessicator to room temperature and the weight was noted after which it was returned into the oven at temperature of 110°C for 30 min until constant weight was obtained: AOAC (2004).

Ash content determination

Five grams of sample was weighed into a previously ignited and cooled silica dish. The dish was ignited first gentle and then at 600°C for 3 h in a muffle furnace (VULCAN^{TM} furnace model 3-1750). The dish and its content were cooled in a dessicator and the remaining residue due to the ash was reweighed.

Crude fat determination

Crude fat was determined by the method of AOAC (2004). This was determined using a Soxtec System HT2 fat extractor. Crude fat was extracted from the sample with hexane, and the solvent evaporated off to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content.

Crude protein determination

Crude protein was determined by Kjeldahl method using Kjeltec^{TM} model 2300, as described in Foss Analytical manual, AB, (2003). The method involved digestion of the sample at 420°C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulphate. The ammonia in the digest ammonium sulphate was then distilled off into a boric acid receiver solution, and then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to

convert from total nitrogen to percentage crude protein (AOAC, 2004).

Pasting properties determination

Pasting properties (peak viscosity, trough viscosity, breakdown viscosity, setback viscosity, peak time and pasting temperature) were determined with a Rapid Visco Analyzer (RVA) (Newport Scientific RVA Super 3) equipped with software. 3.0 g of each sample was weighed in a vessel and 25 ml of distilled water was dispensed into a new test canister. Sample was then transferred into the water surface in the canister.

The paddle was placed into the canister and the blade vigorously jogged through the sample up and down ten times. The canister was then inserted into RVA machine. The measurement cycle (12 min) was initiated by pressing the canister inside the instrument. The temperature- time lag in the RVA was as follows: started at a temperature of 50°C for 1 min, heated from 50 to 95°C in 3 min and subsequently cooled to 50°C over a 4 min period. It was followed by a period of 1 min where the temperature was kept constant at 50°C.

Determination of swelling power and solubility

This was determined by the Leach et al., (1959) method. It involved weighing 1g of milled sample into 100ml conical flask, 15ml of distilled water was added and mixed gently at low speed for 5minutes. The slurry was heated in a thermostated water bath (Thelco model 83, USA) at 80°C for 40 min. During heating, the slurry was stirred gently to prevent dumping of the starch. The content was transferred into a pre weighed centrifuge tube and 7.5 ml distilled water was added.

The tubes containing the paste were centrifuged at 2,200 rpm for 20 min using Sorvall glc-1 table top centrifuge (model 06470, USA). The supernatant was decanted immediately after centrifuging into a preweighed can and dried at 100oC to constant weight. The weight of the sediment and weight of soluble were taken and recorded.

Determination of water binding capacity

This was determined using the method described by Medicalf and Gilles (1965). 2.5 g of each sample was weighed in a tared % 50 ml centrifuge tube and 37.5 ml of distilled water was added. The tube was capped and agitated on a wrist action shaker for 1 h. Centrifuged for 10 mins at 2.200g or approximately 7,500 rpm and decanted the water. The centrifuge tube with content was weighed and and the amount of water bound was calculated.

Determination of tannin (polyphenols)

Tannin content was determined by the Folin-Dennis colorimetric method described by Joslyn (1970) with modifications. 5 g sample was dispersed in 50 ml of distilled water and shaken. The mixture was allowed to stand for 30 min at 28°C before it was filtered through what man No 42 grade of filter paper. 2 ml of the extract was dispensed into a 50 ml volumetric flask. Similarly, 2 ml standard tannin solution (tannin acid) and 2 ml of distilled water were put in separate volumetric flasks to serve as standard and Folin reagent was added to each of the flask and the 2.5 ml of saturated Na_2CO_3 solution added. The content of each flask was made up to 50 ml with distilled water and allowed to incubate at 28°C for 90 min. Their respective absorbance was measured in a spectrophotometer at 260 nm using the reagent blank to calibrate the instrument at zero.

Determination of Phytic acid content

Phytate was determined by a combination of two methods. The extraction and precipitation of phytic acid was done according to the method of Wheeler and Ferrel (1971). Extraction was done by mechanical shaking of the mixture for 30min and then centrifugation for 15 mins at 3,500 rpm. A 10 ml aliquot of the supernatant was transferred into a 40 ml conical centrifuge tube. 4 ml Ferric chloride solution was added by blowing rapidly from the pipette. The tube and its contents were heated in a boiling water bath for 45 min. The suspension was centrifuged at 3500 rpm for 15mins and the supernatant carefully decanted.

The precipitate was washed twice by dispersing well in 25 ml of 3% TCA, heating in boiling water bath 5min and centrifuging. The volume was made up to 30 ml with distilled water and the mixture heated in boiling water bath for 30 min. The suspension was filtered hot, and precipitate washed with 60ml hot water. The filtrate was discarded and the precipitate from the paper was dissolved with 40ml hot 3.2 M HNO_3 into 100ml volumetric flask.

A 5 ml aliquot was transferred to another 100ml volumetric flask and diluted to 70 ml. 20 ml 1.5 M KSCN was added and volume made to 100ml. Absorbance was read (within 1 min) at 480nm. Iron in the precipitate was then measured according to the method of Makover (1970). A 4:6 Fe/P atomic ratio was used to calculate the phytic acid content.

Determination of apparent amylose content

The apparent amylose was determined by the method of Williams et al. (1985). Starch (500 mg) was defatted by standard AOAC (2004) method using hexane. The defatted starch (100 mg) was dispersed in ethanol (1 ml) and 1 M NaOH (9 ml). The volume was made up to 100 ml with distilled water and a 5 ml aliquot transferred to a volumetric flask containing water, 25 ml. 1 M acetic acid (0.5 ml) and 1 ml iodine solution (0.2% iodine in 2% potassium iodide) were added and the volume made up to 50 ml with water and absorbance recorded at 620 nm.

Starch and sugar contents

The starch and total sugars content were determined using a colorimetric method described earlier by Onitilo et al. (2007). This involves weighing 0.02 g of the sample into a centrifuge tube with 1 ml ethanol, 2 ml distilled water, and 10 ml hot ethanol. The mixture was vortexed and centrifuged at 2000 rpm for 10 min. The supernatant was decanted and used for determining sugar content while the sediment was hydrolyzed with perchloric acid and used to estimate starch content.

Phenol- sulfuric reagent was used for colour development and glucose standards were used for estimation of sugar. The absorbance was read with a spectrophotometer (Milton Roy Spectronic 601, USA) at 490 nm.

Stastical analysis

Data were subjected to analysis of variance (ANOVA) using SAS version 8e (SAS 2001) software at $P<0.05$.The least significance difference (LSD) test was used for mean comparison.

Table 1. Proximate composition (dry weight basis) of selected white yam varieties.

Variety	Moisture (fresh) (%)[a]	Dry matter (%)	Ash (%)	Protein (%)	Fat (%)	Sugar (%)
Ndoni Aggah	62.1±0.117^{e}	37.9±0.117^{b}	2.36±0.033^{b}	2.42±0.134^{e}	0.562±0.224^{fgh}	1.72±0.211^{f}
Oyonku	59.5±0.080^{f}	40.5±0.080^{a}	1.72±0.046^{ef}	3.37±0.037^{b}	2.53±0.157^{b}	3.63±0.011^{d}
Legbaka Gambari	62.7±0.456^{d}	37.3±0.456^{c}	1.68±0.006^{f}	4.90±0.183^{a}	0.454±0.023^{gh}	1.05±0.121^{g}
Ndoni Ekpe	62.0±0.263^{e}	38.0±0.263^{b}	1.95±0.019^{d}	2.54±0.047^{e}	0.356±0.011^{h}	2.15±0.111^{e}
Asoko	65.7±0.012^{b}	34.3±0.012^{e}	1.52±0.031^{g}	2.36±0.235^{e}	1.27±0.151^{c}	6.28±0.193^{b}
Legbaka Awana	63.7±0.059^{c}	36.3±0.059^{d}	2.13±0.081^{c}	3.22±0.169^{cc}	0.904±0.090^{de}	7.02±0.012^{a}
Ndoni Abi	62.1±0.242^{e}	37.9±0.242^{b}	2.93±0.106^{a}	3.18±0.103^{bc}	3.39±0.124^{a}	2.34±0.219^{e}
He - Abalo	63.0±0.111^{d}	37.0±0.111^{c}	2.18±0.063^{c}	1.96±0.058^{f}	0.673±0.034^{efg}	1.61±0.056^{f}
Alomako	68.8±0.042^{a}	31.2±0.042^{f}	2.08±0.037^{c}	2.43±0.109^{e}	0.992±0.007^{d}	2.34±0.065^{e}
Omin	68.7±0.168^{a}	31.3±0.168^{f}	1.83±0.047^{e}	2.68±0.245d^{e}	0.724+0.112^{ef}	5.24±0.023^{c}
Asukwu	62.2±0.068^{e}	37.8±0.068^{b}	1.39±0.008^{h}	2.96±0.203^{cd}	1.39±0.069^{c}	3.60±0.159^{d}
Means	63.7	36.3	1.98	2.91	1.20	3.36
SD	2.91	2.91	0.433	0.788	0.944	2.01
Min	59.5	31.2	1.39	1.96	0.356	1.05
Max	68.8	40.5	2.93	4.90	3.39	7.02
CV (%)	0.281	0.493	2.78	5.43	8.89	4.09
LSD(0.05)	0.399	0.399	0.122	0.352	0.238	0.307
Pr >F (entry)	***[b]	***	***	***	***	***

[a]Parameters mean value ±SD; [b]***, **, *- Significant at P<=0.001, P<=0.01 and P<=0.05, respectively; ns -not significant, P>0.05. Means with the same letter are not significantly different.

RESULTS AND DISCUSSIONS

The results of one way analysis of variance (ANOVA) showed that there were significant varietal differences (P<0.05) among the parameters evaluated. The proximate composition results show that the moisture content of the investigated varieties ranged from 59.5 to 68.8%, ash content ranged from 1.39 to 2.93%, protein content from 1.96 to 4.90%, fat content from 0.356 to 3.39%, free total sugars from 1.05 to 7.02% and total starch from 33.9 to 75.7% (Tables 1 and 2). The bioactive content results showed that vitamin C content ranged from 5.64 mg/100 g to 6.99 mg/100 g, phytate from 1.12 to 2.37%, and tannin from 0.359 mg/g to 1.8 mg/g (Table 3). The functional properties show that the swelling power ranged from 6.66 to 9.68, solubility ranged from 4.72 to 10.0% and water binding capacity ranged from 108 to 144% (Table 4). The pasting properties results show that peak viscosity ranged from 215 to 470 RVU, trough viscosity from 198 to 385 RVU, breakdown viscosity from 8.71 to 84.5 RVU, final viscosity from 278 to 571 RVU, setback viscosity from 66.2 to 204 RVU; peak time ranged from 4.97 to 7.0 min and the pasting temperature from 61.7 to 62.6°C (Table 5). The solubility index and water binding capacity ranged from 4.72 to 10.0% and observed among the water binding capacities of starches from the selected white yam varieties. The chemical composition of yam is characterized by a high moisture content and dry matter which is composed mainly of carbohydrate, vitamins as well as protein and minerals (Osunde, 2008; Ezeocha and Ojimelukwe, 2012). The total starch differed significantly among the different white yam varieties, ranging between 33.9 and 75.7%. *Alomako* variety had the lowest starch content. Decrease in amylose content was observed as amylopectin content increased, this is an indicator that one is a function of the other; however both properties are important in food preparation and development (Eke-Ejiofor and Owuno, 2012).

The amylopectin content of the different white yam varieties was between the range of 61.9 and 75.7%, *Asoko* variety had the highest amylopectin content while *Asukwu* had the lowest value. The amylose content was lower than the amylopectin content in the selected white yam varieties as it was also observed in *Ozibo*, another variety of *D. rotundata* (Okorie et al., 2011). Mali et al. (2004) observed that starch from yam had more amylose content than starches from corn and cassava. Moisture content in the selected varieties was high when compared with those reported in the literature and this might due to the environmental factor. Yam varieties with low moisture content are suitable for high yield flour production (Polycarp et al., 2012). *Oyonku* variety had the lowest moisture contentand therefore may be more suitable for flour production.

The protein values for the selected white yam varieties were significant and higher than the value reported for *D. rotundata* and *Colocasia esculenta,* majority of the selected white yam varieties also had lower fat contents as compared to that of cocoyam (Alinnor and Akalezi,

Table 2. Proximate composition (dry weight basis) of selected white yam varieties.

Variety	Starch (%)[a]	DCHO (%)[b]	TCHO (%)[c]	Amylose (%)	Amylopectin (%)	TME (KJ)[d]
Ndoni Aggah	58.2±0.442[e]	60.0±0.653[ef]	32.6±0.208[ab]	25.3±0.121[f]	74.7±0.121[a]	605±7.16[d]
Oyonku	58.1±2.43[e]	61.8±2.42[df]	32.9±0.159[a]	27.3±0.174[e]	72.7±0.174[b]	701±3.82[a]
Legbaka Gambari	62.6±0.815[d]	63.6±0.936[d]	30.3±0.610[c]	28.3±0.108[de]	71.7±0.108[bc]	605±7.98[d]
Ndoni Ekpe	57.4±0.669[e]	59.5±0.781[f]	33.2±0.186[a]	33.4±0.109[b]	66.6±0.109[e]	609±4.31[d]
Asoko	71.6±0.783[b]	77.8±0.975[b]	29.1±0.366[d]	24.3±0.142[f]	75.7±0.142[a]	573±3.44[f]
Legbaka Awana	75.7±0.333[a]	82.7±0.345[a]	30.1±0.062[c]	27.7±0.078[e]	72.3±0.078[b]	590±0.482[e]
Ndoni Abi	68.9±0.021[c]	71.3±0.198[c]	28.4±0.575[e]	24.4±0.190[f]	75.6±0.190[a]	654±3.26[b]
He - Abalo	49.8±0.657[f]	51.4±0.714[g]	32.2±0.266[b]	30.0±0.200[cd]	70.0±0.200[cd]	595±2.21[f]
Alomako	33.9±0.023[i]	36.2±0.088[i]	25.7±0.108[f]	33.1±1.94[b]	66.9±1.94[e]	507±0.236[g]
Omin	39.7±0.851[h]	44.9±0.874[h]	26.0±0.082[f]	30.3±1.07[c]	69.7±1.07[d]	507±1.28[g]
Asukwu	47.3±0.573[g]	50.9±0.732[g]	32.0±0.058[b]	38.1±2.14[a]	61.9±2.14[f]	637±0.157[c]
Means	56.7	60.0	30.2	29.3	70.7	598
SD	13.1	13.9	2.66	4.26	4.26	57.2
Min	33.9	36.2	25.7	24.3	61.9	507
Max	75.7	82.7	33.2	38.1	75.7	701
CV (%)	1.55	1.58	1.06	2.92	1.21	0.547
LSD(0.05)	1.96	2.11	0.717	1.90	1.90	7.29
Pr >F(Entry)	***[e]	***	***	***	***	***

[a]Parameters mean value ±SD; [b]DCHO = Digestible carbohydrate; [c]TCHO = Total carbohydrate[d]; TME = total metabolisable energy, KJ = Kilojoules; [e]***, **, * -Significant at P<=0.001, P<=0.01 and P<=0.05, respectively. ns- not significant P>0.05. Means with the same letter are not significantly different.

Table 3. Bioactive contents (dry weight basis) of selected white yam varieties.

Variety	[a]Vitamin C (mg/100 g)	Phytate (mg/g)	Tannin (mg/g)
Ndoni Aggah	6.35 ± 0.145[d]	2.37 ± 0.04[a]	0.64 ± 0.017[ef]
Oyonku	6.04 ± 0.082[e]	1.73 ± 0.044[e]	0.68 ± 0.017[d]
Legbaka Gambari	5.64 ± 0.071[f]	1.12 ± 0.025[h]	1.18 ± 0.019[a]
Ndoni Ekpe	6.67 ± 0.076[c]	2.29 ± 0.024[ab]	0.74 ± 0.018[c]
Asoko	6.99 ± 0.016[a]	1.55 ± 0.021[f]	0.89 ± 0.010[b]
Legbaka Awana	6.83 ± 0.004[abc]	1.40 ± 0.052[g]	0.67 ± 0.000[ed]
Ndoni Abi	6.73 ± 0.097[bc]	1.75 ± 0.023[e]	0.69 ± 0.001[d]
He - Abalo	6.17 ± 0.068[ed]	1.47 ± 0.053[gf]	0.69 ± 0.008[d]
Alomako	6.88 ± 0.064[ab]	2.16 ± 0.047[c]	0.36 ± 0.019[g]
Omin	6.96 ± 0.071[a]	1.91 ± 0.047[d]	0.62 ± 0.027[f]
Asukwu	6.12 ± 0.069[e]	2.24 ± 0.025[bc]	0.64 ± 0.026[ef]
Means	6.49	1.82	0.708
SD	0.448	0.412	0.200
Min	5.64	1.12	0.359
Max	6.99	2.37	1.18
CV (%)	1.26	2.22	2.45
LSD(0.05)	0.182	0.090	0.039
Pr > F Entry)	***[b]	***	***

[a]Parameters mean value ±SD; [b]***, **, * -Significant at P<=0.001, P<=0.01 and P<=0.05 respectively; ns- Not significant at P>0.05. Means with the same letter are not significantly different.

2010). *Legbaka Gambari* variety had the highest protein content, while *Legbaka awana* variety had the highest sugar content. It was reported that yamsgenerally have considerably higher protein content than the 1.2-1.8% on

Table 4. Functional properties of flour from selected white yam varieties.

Variety	Swelling power[a]	Solubility (%)	Water binding capacity (WBC) (%)
Ndoni Aggah	8.69 ± 0.094[a]	7.85 ± 0.016[bh]	126 ± 0.812[abcd]
Oyonku	8.21 ± 0.158[cd]	6.67 ± 3.15[bc]	116 ± 0.132[cd]
Legbaka Gambari	7.07 ± 0.016[e]	4.72 ± 0.150[c]	133 ± 0.779[bcd]
Ndoni Ekpe	7.04 ± 0.128[e]	6.48 ± 0.117[bc]	124 ± 0.258[abc]
Asoko	7.94 ± 0.192[d]	7.94 ± 0.176[ba]	132 ± 1.01[abc]
Legbaka Awana	7.71 ± 0.203[d]	10.0 ± 1.68[a]	133 ± 0.341[a]
Ndoni Abi	8.80 ± 0.531[b]	7.88 ± 0.184[ba]	144 ± 0.053[abc]
He - Abalo	6.66 ± 0.557[e]	4.84 ± 2.01[c]	134 ± 0.208[abc]
Alomako	9.04 ± 0.029[b]	4.73 ± 0.011[c]	108 ± 27.6[d]
Omin	9.68 ± 0.037[a]	6.47 ± 0.689[bc]	143 ± 1.39[ab]
Asukwu	8.09 ± 0.258[d]	7.52 ± 0.327[abc]	130 ± 2.28[abc]
Means	8.09	6.83	129
SD	0.930	1.65	10.5
Min	6.66	4.72	108
Max	9.68	10.0	144
CV (%)	3.23	18.7	6.39
LSD(0.05)	0.582	2.85	18.4
Pr > F(Entry)	***[b]	*	*

[a]Parameters mean value ±SD; [b]***, **, * - Significant at P<=0.001, P<=0.01 and P<=0.05 respectively; ns- not significant at P>0.05; Means with the same letter are not significantly different.

dry weight basis as reported by Charles et al. (2005) for cassava. The protein contents observed in the selected varieties of white yam were however lower than reported value of 10.27% for *D. alata*. *He-Abalo* had the lowest protein value. The vitamin C contents of the varieties fall within the range of 4.00 - 18.00 mg for edible yam species (Osagie, 1992) and between 6.5 and 11 mg/100g as observed by Coursey and Aidoo (1966). *Asoko* variety had the highest vitamin C content. However, different cooking techniques may affect the retention of vitamin C in yams.

The ash contents observed in the selected white yam varieties were lower than those obtained from other *Dioscorea* spp. reported by Shanthakumari et al. (2008)

Peak viscosity indicates the water binding capacity of the starch or mixture occurs at the equilibrium point between swelling causing an increase in viscosity rupture and alignment causing its decrease (Adegunwa et al., 2011). It is also indicative of the strength of the pastes which are formed from gelatinization during processing in food applications (Eke-Ejiofor and Owuno, 2012). There was no significant difference between the pasting temperatures of the selected white yam varieties. Similar ranges were also observed by Adegunwa et al. (2011). Flours from all the selected *D. rotundata* varieties had peak viscosity higher than flour from *D. alata,* but only a few were higher than that of cassava flour (Babajide and Olowe, 2013). Swelling power, as described by Richard et al. (1991) is a factor of the ratio of amylose toamylopectin, *Omin* variety had the highest swelling power while *He-Abalo* variety had the lowest. *Asukwu* variety had the highest, peak, trough, breakdown and final viscosity values, while *Legbaka Gambari* variety had the highest setback viscosity value. The pasting temperature is the temperature at which the viscosity starts to rise (Liang and King, 2003), thus, the lower the pasting temperature, the faster the swelling. Flours from the selected *Dioscorea rotundata* varieties had higher pasting temperature than *D. dumetorum* flour and wheat flour (Eke-Ejiofor and Owuno, 2012).

The water binding capacity varied significantly among the different varieties studied (P<0.05). Tannins are water-soluble polyphenols that are present in many plant foods (Chung et al., 1998). These phenolic compounds usually interfere with iron absorption through a complex formation with iron in the gastrointestinal tract, decreasing the bioavailability of iron (Adegunwa et al., 2011), though tannins have anti-carcinogenic and anti-mutagenic potentials due to their antioxidative property (Chung et al., 1998). The tannin contents recorded in this study were however significant at P<0.001. The tannin content was similar to that observed by Adegunwa et al. (2011) and also falls within the range observed for other *Dioscorea* spp. (Shanthakumari et al., 2008). *Legbaka*

Table 5. Pasting properties of flour from selected white yam varieties.

Variety	Peak 1[a]	Trough 1	Breakdown	Final viscosity	Setback	Peak time	Pasting temperature
Ndoni Aggah	337 ± 9.37^{c}	300 ± 1.12^{c}	37.665 ± 8.25^{b}	402 ± 4.77^{d}	103 ± 3.66^{ef}	5.84 ± 0.049^{ef}	61.9 ± 0.141^{a}
Oyonku	231 ± 5.77^{h}	222 ± 6.42^{e}	8.71 ± 0.651^{f}	311 ± 5.19^{g}	89.0 ± 3.66^{fg}	6.30 ± 0 .042^{cb}	61.9 ± 0.177^{a}
Legbaka Gambari	245 ± 2.71^{g}	213 ± 1.94^{e}	32.04 ± 0.764^{bc}	418 ± 3.30^{cd}	204 ± 1.24^{a}	6.20 ± 0 .000^{cbd}	61.8 ± 0.247^{a}
Ndoni Ekpe	289 ± 4.72^{e}	266 ± 9.02^{d}	22.375 ± 4.31^{cde}	371 ± 3.71^{e}	104 ± 5.30^{ed}	5.53 ± 0.000^{f}	61.7 ± 0.354^{a}
Asoko	215 ± 3.95^{i}	198 ± 3.30^{f}	17.46 ± 0.651^{def}	278 ± 2.88^{h}	80.1 ± 0.420^{gh}	7.00 ± 0.000^{a}	62.3 ± 0.566^{a}
Legbaka Awana	275 ± 4.48^{ef}	264 ± 3.66^{d}	10.83 ± 8.13^{f}	330 ± 0.420^{f}	66.2 ± 4.07^{h}	6.44 ± 0.049^{b}	61.9 ± 0.071^{a}
Ndoni Abi	269 ± 4.13^{f}	253 ± 0.18^{d}	15.875 ± 3.95^{def}	370 ± 2.72^{e}	117 ± 2.54^{d}	5.90 ± 0.141^{ed}	61.9 ± 0.071^{a}
He - Abalo	311 ± 5.78^{d}	287 ± 2.83^{c}	23.75 ± 2.94^{cd}	431 ± 10.31^{c}	144 ± 13.1^{c}	6.90 ± 0.141^{a}	61.9 ± 0.035^{a}
Alomako	356 ± 5.78^{b}	344 ± 12.55^{c}	12.045 ± 4.07^{ef}	461 ± 19.50^{b}	117 ± 6.95^{d}	6.87 ± 0.191^{a}	62.6 ± 1.379^{a}
Omin	355 ± 12.90^{b}	341 ± 16.86^{b}	14.375 ± 3.95^{def}	423 ± 15.80^{c}	81.8 ± 1.06^{g}	6.03 ± 0.424^{ed}	61.9 ± 0.141^{a}
Asukwu	470 ± 4.77^{a}	385 ± 1.29^{a}	84.54 ± 6.07^{a}	571 ± 8.84^{a}	186 ± 10.1^{b}	4.97 ± 0.049^{g}	61.9 ± 0.035^{a}
Means	305	279	25.4	397	118	6.18	62.0
SD	72.9	59.3	21.6	80.2	44.0	0.621	0.256
Min	215	198	8.71	278	66.2	4.97	61.7
Max	470	385	84.5	571	204	7.00	62.6
CV (%)	2.13	2.27	18.4	2.12	5.50	2.63	0.748
LSD(0.05)	14.5	14.1	10.4	18.7	14.4	0.362	1.03
Pr > F(Entry)	***[b]	***	***	***	***	***	ns

[a]Parameters mean value ±SD; [b]***, **, * -Significant at P<=0.001, P<=0.01 and P<=0.05 respectively; ns -Not significant at P>0.05. Means with the same letter are not significantly different.

Gambari variety had the highest tannin content. Phytate has a strong ability to chelate multivalent metal ions,specially zinc, calcium and iron, making them biologically unavailable, it is also regarded as an anti-nutritional factor in the diet of humans because of their inability to utilize it (Bohn et al., 2008). The phytate values recorded in selected white yam varieties were also significant (P< 0.001). The presence of enzyme inhibitors in yams could affect digestion of starch and protein, limiting their utilization as food (Polycarp et al., 2012). This study observed low levels of tannin and phytate in the selected varieties of white yam.

Lower levels of tannin and phytate were also recorded in yam varieties studied by Polycarp et al. (2012) and are recommended as safe for food processing application.

Conclusion

The result of this study revealed that the physical and chemical characteristics of these yam high yielding varieties were similar to those reported for most yam varieties in other parts of Nigeria. These yam varieties have better functional and pasting properties, hence better poundability and mealiness. They also have a great potential as source of bioactive compounds and protein for the people in the zone.

Conflict of interests

The authors did not declare any conflict of interests.

REFERENCES

Adegunwa MO, Alamu EO, Omitogun LA (2011). Effect of processing on the nutritional contents of yam and cocoyam

tubers. J. Appl. Biosci. 46:3086-3092.
Alinnor IJ, Akalezi CO (2010). Proximate and Mineral Compositions of *Dioscorea rotundata* (white yam) and *Colocasia esculenta* (white cocoyam). Pak. J. Nutr. 9 (10): 998-1001.
Araghiniknam M, Chung S, Nelson-White T, Eskelson C, Watson RR (1996). Antioxidant activity of *Dioscorea Dioscorea* and dehydroepiandrosterone (DHEA) in older humans. Life Sci. 59:PL147-157.
Association of Official Analytical Chemists, AOAC (2004). Official Methods of Analysis of the Association of Official Analytical Chemists. Arlington. Virginia.
Babajide JM, Olowe S (2013). Chemical, functional and sensory properties of water yam - cassava flour and its paste. Int. Food Res. J. 20(2):903-909
Baquar SR, Oke OL (1976). Protein in Nigerian yams (Dioscorea spp.). Nutrient Reports International 14:237-248.
Bergh K, Orozco P, Gugerty MK, Anderson L (2012). Yam value chain: Nigeria. Evans School Policy and Analysis Research Brief: No. 207
Bohn L, Meyer AS, Rasmussen SK (2008) Phytate: impact on environment and human nutrition. A challenge for molecular breeding. J. Zhejiang Univ. Sci. B 9(3):165-191.
Bradbury JH (1988). The chemical composition of tropical root crops. ASEAN Food J. 4:3-13.
Charles AL, Sriroth K, Huang TC (2005). Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. Food Chem. 92: 615-620.
Chung KT, Wong TY, Wei CI, Huang YW, Lin Y (1998) Tannins and human health: a review. Crit. Rev. Food Sci. Nutr. 38(6): 421-64
Coursey DG' Aidoo A (1966) Ascorbic acid levels in Ghanaian yams. J. Sci. Food Agric. 17(10):446 - 449.
Coursey DG, Haynes PH (1970). Root crops and their potential as in the tropics. World Crops 22:261-265.
Eke-Ejiofor J, Owuno F (2012). Functional and Pasting Properties of Wheat/ Three-leaved Yam *(Dioscorea dumentorum*) composite flour blend. Global Res. J. Agric. Biol. Sci. 3(4):330 -335.
Ezeocha VC, Ojimelukwe PC (2012). The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscorea alata*). J. Stored Prod. Postharvest Res. 3(13):172 - 176.
FAOSTAT (2013). FAO Statistical databases http://www.faostat.fao.org (Accessed 17/07/2013)
Farombi EO, Britton G, Emerole GO (2000). Evaluation of the antioxidant activity and partial characterization of extracts from browned yam flour diet. Food Res. Int. 33:493-499.
Food and Agricultural Organization (FAO) (2008). Statistical data. http://www.fao.org
Foss Analytical AB (2003). Manual for Kjeltec System 2300 Distilling and Titration Unit.
Hikino H, Konno C, Takahashi M, Murakami M, Kato Y, Karikura M, Hayashi T (1986). Isolation and hypoglycemic activity of dioscorans A, B, C, D, E, and F; glycans of Dioscorea japonica rhizophors. Planta Med. 3:168-171.
Hu K, Dong A, Yao X, Kobayashi H, Iwasaki S (1996). Antineopastic agents: I. Three spirostanol glycosides from rhizomes of Dioscorea collettii var. hypoglauca. Planta Med. 62:573-575
Hu K, Dong A, Yao X, Kobayashi H, Iwasaki S, Jing YK (1999). A new pregnane from Dioscorea collettii var. hypoglauca. J. Nat. Prod. 62: 299-301.
IITA (2009). Yam. www.iita.org (Accessed 16/07/13).
Izekor OB, Olumese MI (2010). Determinant of yam production and profitability in Edo State, Nigeria. Afr. J. Gen. Agric. 6 (4):205-210.
Joslyn MA (1970). Tannins and related phenolics. In: Methods in food analysis. pp. 701-725.
Kelmanson JE, Jager AK, Van Staden J (2000). Zulu medicinal plants with antibacterial activity. J. Ethnopharmacol. 69:241-246.
Lasztity R, Hidvegi M, Bata A (1998). Saponins in food. Food Rev. Int. 14(4):371-390.
Leach HW, McGowen LD, Schoch TJ (1959). Structure of the starch granule I: Swelling and solubility patterns of various starches. Cereal Chem. 36: 534-544.
Liang X, King JM (2003). Pasting and crystalline property Differences of Commercial and Isolated Rice Starch with Added Amino Acids. J. Food Sci. 68:3.
Makover RU (1970) Extraction and determination of phytic acid in beans. Cereal Chem. 47:288-296.
Mali S, Karam LB, Ramos LP, Grossmann MV (2004). Relationships among the composition and physicochemical properties of starches with the characteristics of their films. J. Agric. Food Chem. 52(25):7720-7725.
Marcus DL, Thomas C, Rodriguez C, Simberkoff K, Tasi JS, Strfaci JA, Freedman ML (1998). Increased peroxideratoin and reduced antioxidant enzyme activity in Alzheimer's disease. Exp. Neurol. 150: 40-44.
Medicalf DG, Gilles KA (1965). Wheat Starches I: Comparison of physicochemical properties. Cereal Chemistry 42:558-568.
Okorie PA, Okolie EC, Ndie EC (2011). Functional and Pasting Properties of Lesser Known Nigerian Yams as a Function of Blanching Time and Particle Size. Adv. J. Food Sci. Technol. 3(6):404-409.
Onitilo AA, Sanni LO, Daniel I, Maziya-Dixon B, Dixon A (2007). Physicochemical and functional properties of native starches from cassava varieties in southwest Nigeria. J. Food Agric. Environ. 5(3,4):108-114
Opara LU (1999). Yam storage. In: Bakker-Arkema et al., (eds). CIGR Handbook of Agricultural Engineering Volume IV Agro Processing. The American Society of Agricultural Engineers, St. Joseph, MI. pp. 182-214.
Opara LU (2003). Yams: Post-Harvest Operation. http://www.fao.org/fileadmin/user_upload/inpho/doc/Post_Harvest_Compendium_-_Yams.pdf
Osagie AU (1992). The yam tuber in storage. Post Harvest Research Unit, University of Benin, Nigeria. pp. 107-173.
Osunde ZD (2008) Minimizing Postharvest Losses in Yam (*Dioscorea spp.*): Treatments and Techniques. International Union of Food Science & Technology.
Polycarp D, Afoakwa EO, Budu AS, Otoo E (2012). Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (*Dioscorea*) germplasm. Int. Food Res. J. 19 (3):985-992
Richard JR, Asaoka MA, Blanshard JM (1991). The physico-chemical properties of cassava starch. Trop. Sci. 31:11189-207
Sanusi WA, Salimonu KK (2006). Food security among households: evidence from yam production economics in Oyo state, Nigeria. Agric. J. 1: 249 - 253
Shanthakumari S, Mohan VR, De Britto J (2008) Nutritional evaluation and elimination of toxic principles in wild yam (*Dioscorea* spp.) Trop. Subtrop. Agroecosystems 8(3):319-325
Undie AS, Akubue PI (1986). Pharmacological evaluation of Dioscorea *dumentorumdumentorum* tuber used in traditional antidiabetic therapy. J. Ethnopharmacol. 15:133-144.
Waitt AW (1963). Yam: Dioscorea species. Field Crop Abstract 16(3): 145-157.
Wheeler EL, Ferrel RE (1971). A method for Phytic acid determination in wheat fractions. Cereal chem. 48:312-316.
Williams VR, Wu W, Tsai HY, Bates HG (1985) Varietal differences in amylose content of rice starch. J. Agric. Food Chem. 6:47-48.