Phytochemical, Chemical Composition and Functional Properties of Yam Cultivars Grown in Wukari, Nigeria

[1]Ayo, J.A., *Ojo, M.O., [1]Omelagu, C.A., [1]Ayila, D. and [1]Okpasu, A.A.
[1]Department of Food Science and Technology,
Federal University Wukari, Nigeria.
*University of Mkar , Nigeria
Correspondence: jeromeayo@gmail.com

Abstract

This study investigated the physicochemical and chemical properties of six yam cultivars grown in wukari metropolis. The six yam cultivars were gbangu, mumuye, agbo, ogoja, anumber and aerial yam. The flours were analyzed using standard methods for proximate, physicochemical and phytochemical properties. The results showed that the moisture content, fat, ash, crude fiber, crude protein and carbohydrate ranges from 6.69±0.30-8.53±0.12,0.40±0.01-0.49±0.03,1.79±0.01-3.15±0.01,1.07±0.01-1.84±0.04,4.68±0.04-5.87±0.04 and 83.59±0.05-86.10±0.05, respectively, with aerial yam having the highest values of ash (3.15±0.01%), crude fiber (1.84±0.04%), and gbangu having the highest crude protein (5.87±0.04%) while anumber highest carbohydrate (86.10±0.05%). The Phytochemical composition of yam flour showed that the hydrogen cyanide, phytate, oxalate, and phenol ranges from 0.600±0.00-1.48±0.02, 0.39±0.02-0.87±0.04,0.04±0.03-1.25±0.01,and 0.26±0.04,-0.37±0.03 and 0.26±0.04-0.37±0.03, respectively, with aerial yam having hydrogen cyanide (1.40±0.02[a]mg/100g), phytate (0.87±0.04mg/100g) and oxalate (1.25±0.01mg/100g). The pasting properties of yam flour showed that the peak, trough, breakdown, final and setback viscosity, peak time, paste temperature ranges from 107.71±2.53-534.13±19.27, 102.42±2.47-353.38±7.01, 5.29±0.06-280.92±30.92, 143.38±3.12-592.46±5.71, 40.96±0.65-239.09±1.29, 5.04±0.05-7.00±0.00, and 82.56±1.50-94.13±0.60 respectively with ogoja having the highest value of trough viscosity (353.38±7.01RVU), final viscosity (280.92±30.92RVU), setback viscosity (239.09±1.29RVU), and mumuye, aerial yam have highest peak viscosity (534.13±19.27RVU), breakdown viscosity (280.92±30.92RVU) and peak time (7.00±0.00RVU). The functional properties of yam flours cultivars result showed that the water absorption, swelling capacity, emulsion, loose and packed density, foaming at 15,30sec and 1min, from 2.32±0.14-2.76±0.18, 2.54±0.08-2.79±0.05, 2.45±0.05-4.91±0.64, 2.54±0.08-2.79±0.05, 2.45±0.05-4.91±0.64, 40.29±2.58-55.77±0.91, 0.41±0.01-0.51-0.04, 0.54±0.02-0.70±0.00, 10.11±1.28-24.04±1.36, 7.50±1.25-14.10±0.28, 5.00±2.36-20.00±1.54 respectively with mumuye having the highest water absorption (2.76±0.18g/ml), foaming stability for 15,30sec and 1min, (24.04±1.36g/ml) (14.10±0.28g/ml) (20.00±1.54g/ml) and gbangu having highest emulsion capacity (55.77±0.91g/ml), loose density (0.51-0.04 g/ml). The study showed the existence of significant difference, (p>0.05) within the cultivars for the various assessed parameter. *Gbangu, Ogoja, Mumuye,* and *agbo* cultivars have great potentials for moulding (dough) while *anumber and aerial* yam could be best for chips/discrete based on their pasting and functional properties. The relatively high anti-nutrient components of aerial yam call for appropriate pretreatment reduce the effect.

Keywords: phytochemical, proximate composition, functional, yam cultivars

Introduction

Yams, the most important staple food in West Africa, after cereals (Ekwu *et al*., 2005; Shajeela *et, al*., 2011), belong to the Dioscoreaceae family (Shajeela *et. al*., 2011). Yam, with its appreciable content of essential dietary nutrients, has been reported to have nutritional superiority when compared with other tropical root crops (Maneenoon *et al*., 2008; Arinathan *et al*., 2009; Shajeela *et al*., 2011). About 94 % of the world production of yams is in Africa and Nigeria is the leading producer in the continent (Akinwande *et al*., 2008). The important yam species in Nigeria include *Dioscorea rotundata* (white yam), *Dioscorea alata* (white yam), *Dioscore acayensis* (yellow yam), *Dioscorea bulbifera* (aerial yam or air potato), *Dioscorea esculenta* (Chinese yam) and *Dioscorea dumentorium* (trifoliate yam).

The main shelf- stable product of yam is the traditional yam flour (*elubo*) with little or no industrial applications. High- quality yam flour is a novel product of yam which is produced from wholesome fresh tubers, and characterised as odorless and crystal white, and free from foreign or extraneous material (Akinwande *et al*., 2008). It could find wide applications in the baking and confectionery industries. Traditional foods derivable from yam tubers include chips, *fufu*, *amala* and pounded yam. Yams are generally consumed boiled, with stew or sauce, palm oil and salt or with vegetables. They can also be roasted, fried or baked.

Nutritionally, yam contains; 17, 79, 2.78, 0.28, and 1- 3% of carbohydrate, water, protein, fats, mineral salt and vitamins such as 6, 3.5, 2.5, 9.5, 28.5, 5, 2 and 2% foliates, niacin, riboflavin, thiamine, vitamin C, vitamin A, vitamin A, vitamin E, and vitamin K on wet weight basis (Purseglovç, 2001). Recent research in Nigeria have revealed and identified several cultivars of yam, including (*"abgo", "mumuye". "ogoja", gbangu", "aerial yam"'anumber"*(Afoakwa and Sefa- Dedeh, 2001).

Yam have been researched into severally, including ("pipa", "dan-anacha","mumuye". "ogoja", gbangu",) by Raymond (2014), based on effect of sodium metabisulphite on the proximate, functional and pasting properties of yam flours from varieties of D. rotundata. The major constraint of fresh yam cultivars is their short shelf life during storage. *D. rotundata* and *D. alata* possesses diverse and unique quality characteristics worth exploiting, especially in the food industry. These characteristics of *D. rotundata* coupled with the flexibility in production gives it an advantage for sustainable cultivation, especially when yam production seems to be on the decline as a result of high cost of production, low yields and post-harvest losses among others (olayemi *et al.,* 2012). Products diversification seems to be an obvious option for a better impact.

Discriminate use of fresh yam tubers in production of yam products have been identified to lead to wastage or low acceptability. Specific properties of yam have been identified to be responsible for the acceptability of yam products. Information (functional properties) is needed to identify cultivars for pounding, boiling and frying.

The inability of consumers and processor to identify specific cultivars of yam for appropriate usage could result into under utilization and economic losses. The research was aimed at characterising and grouping the cultivars of yam into appropriate product groups which will consequently classifying, improve their right choice for appropriate food products. The outcome of the research may reduce wrong choice of yam cultivars for appropriate yam product.

MATERIALS AND METHODS

Materials

The yam samples used in this study were obtained from Wukari and Kyado Yam Market, Nigeria. Cultivars collected included: *Dioscorea rotundata* (mumuye, gbangu and ogoja white yam), *Dioscorea alata* (agbo 'water yam'), *Dioscorea bulbifera* (aerial yam), and *Dioscorea dumentorium* (cultivar anumber'bitter yam').

Methods

Sample Preparation/Processing of the instant flours

The yam cultivars were *ogoja. mumuye, gbangu, aerial yam, anumber,* and *agbo* yam. The yam tubers were peeled (knife), washed (clean water) sliced into fairly uniform sizes, blanched at (60 ^{0}C for *5mins*), sun dried (three days), dry milled (attrition mill), sieved to produce a fine powder and packed in polyethene.

Proximate Composition of different cultivars of yam flour.

The moisture, protein, fats, and ash content were determined using AOAC (2005) methods, while carbohydrate was calculated by difference (Ihekoronye and Ngoddy. 1999).

Pasting property determination of Yam Flour

Pasting characteristics was determined with a Rapid Visco Analyzer (RVA), (Model RVA3Dt, Network Scientific, Australia). First, flour samples (2.5g) were weighed into a dried empty canister; then 25ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 ° C to 95 ° C with a holding time of two minutes, followed by cooling to 50 ° C with 2 minutes holding time. The rate of heating and cooling was at a constant rate of 11.25 ° C per mm. The pasting temperature, viscosity at 95°C, stability, cooking time and setback viscosities were read off the amylograph. Peak viscosity, trough, breakdown, final viscosity, and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer (1ITA, 2001).

Functional properties determination of Yam flour

Determination of water absorption capacity

Water absorption capacity was determined by the method described by Abbey and lbeh (2000). Flour samples (1 g) of each treated sample was weighed separately and poured into clean centrifuge tubes of known weights. Distilled water was mixed with the flour to make up to 10 ml dispersion. The tubes were then centrifuged at 3500 rpm for 15 minutes. The supernatant was decanted and each tube together with its contents was re-weighed. The gain in mass is the water absorption capacity.

Determination of oil absorption capacity

The method described by Abbey and lbeh (2003) was adopted. One gram of the sample (1 g) was weighed separately into clean centrifuge tubes of known weights. Groundnut oil (10 ml) was mixed with the flour in each tube to make up to 10 ml dispersion; the tubes were centrifuged at 3500 rpm for 15 minutes. The supernatant was discarded and the tubes re-weighed. The gain in mass is the oil absorption capacity.

Determination of emulsion capacity

The emulsion (1g flour, 10 ml distilled water and 10 ml refined vegetable oil) is prepared in calibrated tube. The emulsion is centrifuged at 200 rpm for 5 min. The ratio of the height of the emulsion layer to the total height of the mixture is calculated as the emulsion activity expressed in percentage (Onimawo and Akubor, 2001).

Determination of Bulk density

The method by Onwuka (2005) was adopted for determining the bulk density. A graduated cylinder 10 ml was weighed dry and gently filled with flour sample. The bottom of the cylinder was then tapped gently on a laboratory bench several times. This continues until no further diminution of the test flour in the cylinder after filling to mark, was observed. Weight of cylinder plus flour was measure and recorded.

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

Determination of swelling index

The swelling index was determined according to the method described by Ukpabi and Ndimele (1990). Three gram (3 g) portions of the flour were transferred into cleans graduated (50 ml) cylinders. The flour samples were gently filled and the volumes noted. Distilled water (30 ml) was added to each sample. The swirled cylinder was allowed to stand for 60 mm, while the change in volume was recorded every 15 min. The swelling index of each flour sample was calculated as multiple of the original volume as done by (Ukpabi and Ndimele, 1999).

Foaming capacity and stability

Two grams (2 g) of flour sample and 50 ml distilled water was mixed in a blended at room temperature 29 º C. The suspension was stirred for 5 min at 1000 rpm using centrifuge. The total volume after 30 sec was recorded. It was allowed to stand at room temperature for 30 min and the volume of foam recorded. The percentage increase in volume after 30 sec is expressed as foaming capacity. The method used by Nwosu *et al,* (2010) was used with a slight modification.

Determination of phytochemical composition
Phytate determination

Four gram (4g) of the sample was soaked

into 100 mL of 2% hydrochloric acid for five hours and was filtered. A volume of 25 mL of the filtrate was taken into a conical flask and 5 mL of 0.3% ammonium thiocyanate solution was added. The mixture was titrated with a standard solution of iron (III) chloride until a brownish-yellow color persists for 5 min (AOAC, 2005).

Oxalate determination

The oxalate content in the yam flour samples was analyzed using the calcium oxalate precipitation method as used in the Association of Official Analytical Chemists' (AOAC, 2005), with slight modifications. Five (5) g of the ground samples were weighed into a 250 ml Erlenmeyer flask, 100 ml of 2N HCl was added and mixed thoroughly on orbital shaker at 120 rev/min for 2 hours. The mixture was then centrifuged at 3000 rpm for 5 min. The mixture was filtered and 5 ml of phosphoric tungstate reagent (prepared by adding 12 g of Sodium tungstate dissolved in water to 20 ml of phosphoric acid and the solution was made up to 500 ml with distilled water) was added to 25 ml aliquots of the filtrate. The solution was mixed thoroughly and kept in the cold room overnight. The next day, the solution was centrifuged, filtered and 2 drops of methyl red solution was added to 20 ml aliquots of the filtrate. The mixture was neutralized with drops of ammonia until pink colour changes to faint yellow. Five (5) ml of calcium chloride buffer was added; mixed thoroughly and allowed to stand undisturbed overnight. The solution was filtered again the next day, washed with chloride free distilled water (this was tested with silver nitrate, $Ag(NO_3)$) and the precipitate together with the filter paper were transferred to the same beaker in which it was kept overnight. This was followed by the addition of 50 ml distilled water and 5 ml of $2NH_2SO_4$. The mixture was heated to about 80°C on a water bath and titrated while hot carefully against N/100N/100 $KMnO_4$

Hydrogen Cyanide Determination

Alkaline titration procedure was adopted for determining hydrogen cyanide (Anhwange, 2004). Ten grams (10g) of each of the ground samples were soaked in the mixture of 200 cm^3 of distilled water and 10 cm^3 of orthophosphoric acid. The mixture was kept for 12 hours to release all the bonded cyanide. The mixture was then distilled until 150 cm^3 of the distillate was collected. 20 cm^3 of the distillate was taken into a conical flask containing 40 cm^3 of distilled water, 8 cm^3 of ammonia solution (6 mold·m-3) and 2 cm^3 of potassium iodide (5%) solution was added. The mixture was titrated with silver nitrate (0.02 mold·m-³) to faint but permanent turbidity (1 cm^3 0.02 mold·m-³ $AgNO^3$ ≡ 1.08 mg HCN). Replicates determination were done for each of the samples.

c = 52.04 Va (Ma/Vc)

where Mc is the cyanide concentration (mg/mL), Va the volume (mL) of standard silver nitrate solution

Ma is the concentration (moles/L) of standard silver nitrate solution

Vc the volume (mL) of calibration stock solution titrated

Determination of total phenols

Obadoni and Ochuko (2001) method was used for determination of phenolic component. The sample was boiled with a 50 ml of ether for 14 min. 5 ml of the extract was pipette into a 50 ml flask, then 10 ml of distilled water was added. 2 ml of ammonium hydroxide solution and 5 ml of concentrated amyl alcohol were also added. The sample was made up to mark and left to react for 30 min for colour development. The absorbance of the solution was read using spectrophotometer at 505 nm wavelength.

Statistical Analysis

All data values are in replicate of two and were subjected to Analysis of Variance (ANOVA) using SPSS version 16.00 and Means were separated using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Proximate Composition of Yam Flour

The proximate composition of the yam cultivars are shown below in Figure1. The percentage moisture content ranges from 6.69±0.30 - 8.53±0.12% with mumuye cultivar having the highest moisture content (8.53%). Cultivar *anumber, ogoja,* and aerial yam flours with relatively low moisture content could have a longer shelf life as observed by Abulude, (2006). This was stressed by Ojokoh *et al.* (2010) that, fungal growth in agricultural produce is directly correlated to the moisture content.

The ash content of the yam flours ranges from 1.79±0.01-3.15±0.01%. Which shows significant differences ($p<0.05$) and may be attributed to varietal effect. Comparable ash content (2.50-4.90%) has been reported for *D. alata* tubers (Lebot *et al.*, 2005). The amount of ash in a tuber depends on the type of soil from which it was harvested, the moisture content and the maturity of the crop (Osagie, 1992). The ash content is an indication of minerals present in the flour. The result indicates that the flour of yam cultivars could be a source of mineral elements having nutritional importance.

The crude proteins content of different cultivars of yam flour ranges 4.68±0.04-5.87±0.04%. *Gbangu* cultivar has the highest value (5.87%). Dynamic functions of protein include catalysis of chemical transformations, transport metabolic control and contraction. In their structural functions, proteins provide the matrix for bone and connective tissue, giving structure and form to the human organism (Devlin, 2002).

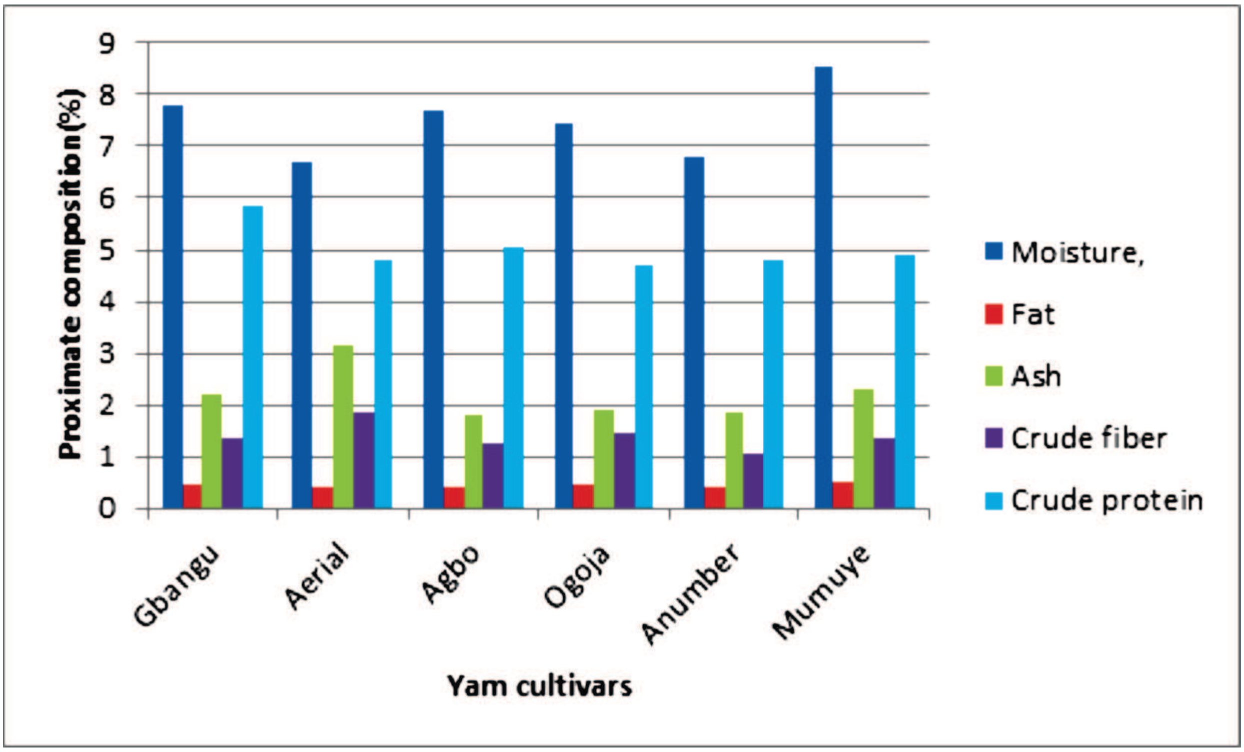

Figure 1: Proximate composition of yam cultivars

The result agreed with the work of Trèche and Agbor-Egbe (1995) which reported a crude protein content of 4.7 to 15.6 g/ 100 g for *D.alata* (water yam). The crude protein content was however higher than the reported value of 3.16% observed in a local variety of *D. Rotundata* by Jimoh *et al*., (2009). The crude fiber result from different yam flour ranges from 1.07±0.01-1.84±0.04%. The aerial yam has the highest value (1.84%). The values observed for different cultivars of yam flours were higher than the reported range of 0.75% to 1.03% for seven water yam varieties (Udensi *et al*., 2008) and 1.65% observed in a local cultivar of *D. rotundata* as reported by Jimoh *et al.,* (2009). The differences observed may be due to cultivar difference or genetics. The relatively high crude fibre content could be useful in providing bulk to foods to relieve constipation (Appiah *et al*., 2011). Crude fiber is a measure of the quantity of indigestible cellulose, pentosans, lignin, and other components of this type may be present in foods. These components have little food value but provide the bulk necessary for proper peristaltic action in the intestinal tract.

The result observed for different cultivars of yam flour for carbohydrates ranges from 83.59±0.10-86.10±0.05%. The primary sugar of the body is glucose. Glucose is the first line or preferential source of energy for the body. The body needs glucose in certain tissues and cells in order for it to function correctly (Anonymous, 2004). The carbohydrate content of flour samples observed agreed with the 75.53 to 87.64% obtained for water yam varieties (Udensi *et al*., 2008). The higher amount of carbohydrate observed in the result suggests that the yam flours could be an important source of energy to consumers (Brown, 1991).

Dry matter content ranged between

91.4±0.11-93.33±0.29 the highest values. A comparable range of 13.68 - 37.4% dry matter content for *D. alata* varieties has been reported in the literature (Maziya-Dixon and Asiedu, 2003; Lebot *et al.,* 2005). Lebot *et al.* (2005) also observed that *D. alata* varieties with good eating quality are characterized by high dry matter, starch and amylose contents. Similarly, Olorunda *et al.* (1999) reported that it is an important chemical index of food quality in root and tuber crops which has an influence on the textural perception of foods.

The fat content values observed for yam cultivars ranges from 0.40±0.03-0.49±0.02%, which compared favorably to that of potato (0.4g/100g) Bradbury and Holloway (1999) and cassava (0.3g/100g-1,(Richard and Coursey., 1991). The relatively higher fat content observed in *mumuye* (0.49±0.03%) suggest the flour could be good flavor retainers and could be rich in fat soluble vitamins, like A, D, E and K.

Phytochemical composition of yam flour

The phytate and oxalate contents of the yam flours range from 0.39±0.02-0.87±0.04mg/100g, and 0.04±0.03-1.25±0.01mg/100g,(Fig.2) respectively. The phytate value observed is relatively lower *to* that (58.6 – 198 mg/100g on cultivars of *D. alata)* reported by Wanasundera and Ravindran (1994). Phytates and oxalates are known to adversely affect mineral bioavailability (Bhandari and Kawabata, 2006). However, Marfo *et al*., (1990) reported that cooking could considerable reduce the effect of phytate levels in tubers including yams. It was also reported that 72hours of fermentation could reduce the phytate levels in yams to 65% (Marfo *et al*., 1990).

The Phenolic value ranges from 0.26±0.04,-0.37±0.03mg/100g, table 4.2 which was relatively higher than observed for *Ipomoea batatus* by Adelusi and Ogundana, (1999). Phenolic compounds have been noted to inhibit the activity of digestion as well as hydrolytic enzymes such as amylase, trypsin, chymotrypsin and lipase (Salunkhe, 1998). Phenolics compounds have been identified to exhibit health related functional properties such as anticarcinogenic, antiviral, antimicrobial, anti-inflammatory, hypertensive and antioxidant activity (Shetty, 1997). The phenolics are water soluble compounds and could be reduced by soaking and cooking (Uzogara *et al* (1990), Shanthakumari *et al.*, 2008).

The hydrogen cyanide in the work generally ranges from 0.600±0.00-1.48±0.02mg/100g, figure 2 and were relatively lower than that observed for *Dioscorea alata, D. cayenensis, and D. rotundata* Esuabana, (2000). Hydrogen cyanide which has been known to inhibit the respiratory chain at the cytochrome oxidase level could be reduced during soaking and cooking (Shanthakumari *et al* 2009). Boiling has also been identified to inactivate all the trypsin inhibitor (Bradbury and Holloway, 1999).

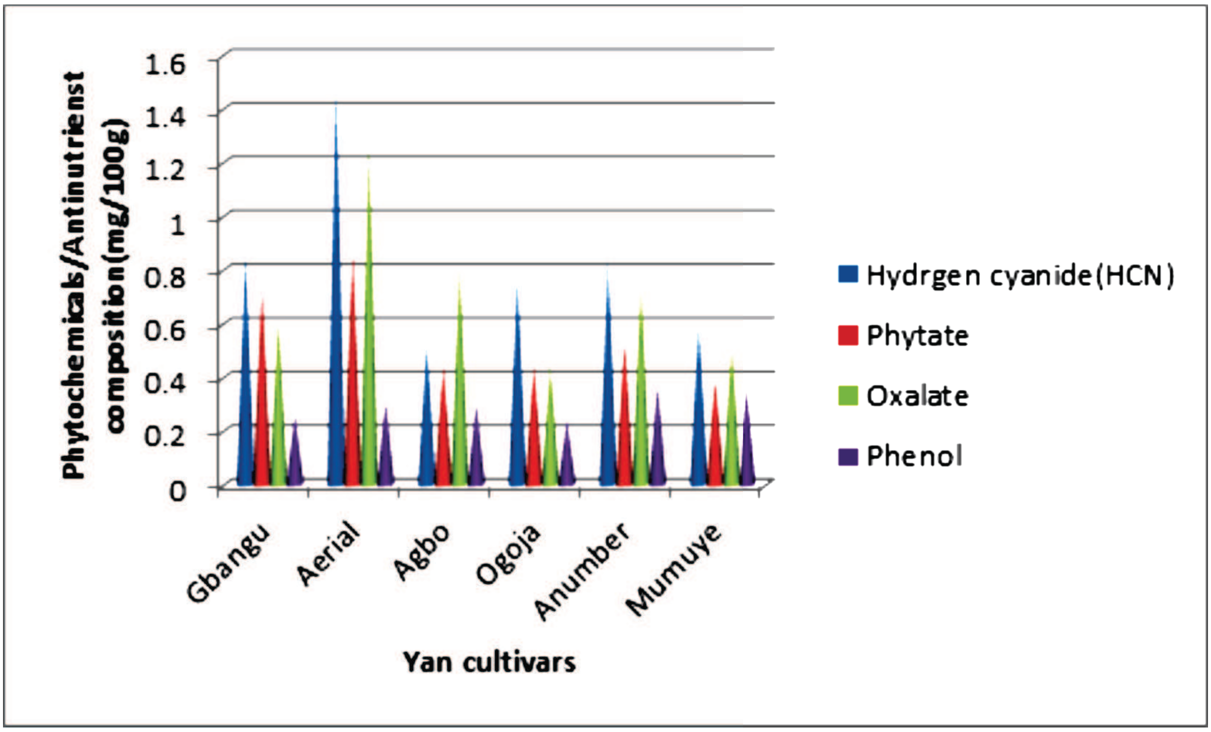

Figure 2: Phytochemical composition of yam cultivars

Pasting properties of different yam flours

The pasting properties of yam flours are shown Table 1. Peak viscosity of the yam flours ranges 107.71±2.53-534.13±19.20RVU. Peak viscosity is the maximum viscosity attained by the paste during the heating cycle (that is from 50 to 95 ^{o}C) and have been attributed to swelling of starch granules and leaching out of the soluble components into the solution. It reflects the ability of starch granules to swell freely before their physical breakdown (Singh *et al.*, 2003) and often correlates with product quality. Yam starches generally have some level of resistance to swelling which in this case is more pronounced in some *D. alata* varieties. Richardson *et al*. (2000) reported that cassava starch has a high peak viscosity because it exhibits a high degree of swelling. High amylose content has been linked to low swelling power due to greater reinforcement of the internal network by amylose molecules (Lorenz and Collins, 1990; Hoover, 2001). High peak viscosity contributes to good texture (molding) of pounded yam and noodle products, which basically depends on high viscosity and moderately high gel strength (Otegbayo *et al*, 2006).

The trough viscosity values for yam flours ranges from 102.42±2.47-353.38±7.01 RVU. Trough viscosities show the ability of dough to withstand shear stress at high temperatures and higher cooked paste stability (Farhat *et al.*, 1999). Starch with a low trough value would have greater need for cross-linking than one with a high value (Oduro *et al.,* 2000). *D. alata* starch could, therefore, be targeted for industrial uses as thickeners because of its paste stability at high temperature. The ability of a paste to withstand the heating and shear stress is an important factor for most food processing operations and could be an index for starch gels (Madsen and Christensen, 1996). High paste stability is a requirement for industrial users of starch (Bainbridge *et al.,* 1996). The pasting temperature of yam flours ranges from 82.56±1.50-94.13±0.6^{0}C. Comparatively, with D. *alata* having the highest value (80^{0}C) and could be attributed to strong bonding forces within the starch granules (Hoover, 2001). Rickard *et al*. (1991) reported that *D. rotundata* behaved quite differently from other yam species in that, at high concentrations, considerable paste breakdown occurred on prolonged heating and stirring, also observed in this study.

The final viscosity of yam flours ranges between143.38±3.12 -592.46±5.17 RVU. The highest final viscosity by cultivar ogoja (592.46±5.17 RVU) could be as a result of its ability to form gel after cooking and cooling (Richardson *et al,* 2000) and high ability to re-crystallize, resulting in progressively higher viscosities during cooling of yam starches (Anonymous, 1990). Aerial yams with lowest final viscosity (143.38±3.12 RVU) exhibit the resistance to swell and gel after cooking.

Table 1: Pasting properties of yam cultivars

Sample	Peak viscosity(RVU)	Trough viscosity(RVU)	Breakdown viscosity(RVU)	Final viscosity(RVU)	Setback viscosity(RVU)	Peak time(S)	Paste Temperature(^{0}C)
Gbangu	507.63±8.07^{b}	332.92±29.22^{b}	174.71±21.16^{b}	508.38±4.89^{b}	175.46±24.34^{c}	5.04±0.05^{f}	85.75±0.00^{d}
Aerial	107.71±2.53^{f}	102.42±2.47^{f}	5.29±0.06^{f}	143.38±3.12^{f}	40.96±0.65^{f}	7.00±0.00^{a}	82.56±1.50^{f}
Agbo	331.92±2.35^{d}	310.54±2.53^{c}	21.38±0.18^{e}	409.88±4.07^{d}	99.34±1.53^{d}	5.54±0.09^{b}	86.87±2.86^{c}
Ogoja	441.79±15.85^{c}	353.38±7.01^{a}	88.42±22.86^{c}	592.46±5.71^{a}	239.09±1.29^{a}	5.17±0.05^{d}	85.30±0.64^{e}
Anumber	160.67±0.47^{e}	111.71±0.06^{e}	48.96±0.53^{d}	197.21±5.01^{e}	85.50±4.95^{e}	5.24±0.05^{c}	94.13±0.60^{a}
Mumuye	534.13±19.27^{a}	253.21±11.02^{d}	280.92±30.29^{a}	478.33±28.99^{c}	225.13±40.02^{b}	5.14±0.09^{e}	89.73±5.62^{b}

Values are means ± standard of duplicate determination
Different superscript in the same row denotes difference at ($p<0.05$)

Setback viscosity of the yam flour ranges from 40.96±065-239.09±1.29 RVU, for the different cultivar of yam flours. High setback value from cultivar Ogoja (239.09±1.29 RVU,) could be associated with cohesive paste (Oduro *et al.*, 2000); a good index for pounded yam or *fufu* (Adebowale *et al.*, (2005); Otegbayo *et al.*, (2006). Mali *et al*. (2003) and Peroni *et al*. (2006) reported that yam starch has a high setback as a result of retrogradation. The lower setback observed for cultivar *agbo* (99.34±1.53RVU), *anumber* (85.50±4.95RVU) and aerial yam (40.96±0.65RVU) flour samples in this study suggest that its flour/starch is relatively more stable when cooked and will have a lower tendency to undergo retrogradation during freeze/thaw cycles (Sackey, 1998).

The results for breakdown viscosities for different yam flours ranges from 5.29±0.06-280.92±30.29 RVU. High breakdown viscosity value is an indication of strong bonding forces between their starch granules as observed for cultivars *mumuye* (280.92±30.29RVU) and Ogoja (174.71±4.89RVU) due to higher values of breakdown viscosity. According to McPherson and Jane (1999), linear and strongly associated molecules keep the integrity of granules providing higher resistance to mechanical agitation and higher pasting temperatures. The high thermal and mechanical stability of *D. alata* could make them good ingredients for processed foods such as instant soups and noodles.

The peak time of the yam flours obtained ranges from 5.04±0.05-7.00±0.00 sec and, respectively. The relatively longer time taken for aerial yam (7.00±0.00sec) indicates stronger bonding forces in their starch granules, high amylose content and lower swelling power (Hoover., 2001), while lower peak time in cultivar *gbangu* (5.04±0.05)is related to strong internal forces between their starch granules (Hoover., 2001).

Functional properties of yam flours from different cultivars

The functional properties of yam flour prepared from *D. rotundata* (*mumuye, gbangu* and *ogoja* white yam), *D. alata* (*agbo*), *D.bulbifera* (aerial yam), and *D. dumentorium (cultivar anumbe*r) are shown in Fig.3.

The packed and loose bulk densities of the flours range between 0.54±0.01-0.70±0.00, 0.41±0.01-0.51±0.01 (g/ml), respectively. The bulk densities observed agreed with the finding of (Sanni *et al*., 2004) of value of 0.68-0.70(g/cm) which could be used in food formulation. Bulk density is important for determining package requirement, materials handling, and application in wet processing in the food industry (Kulkarni *et al*., 1996).

The swelling capacity of flour ranges from 2.45±0.85-4.91±0.64g/ml, which compared favorably with the findings (3.89 and 6.63%) Jimoh *et al*. (2009) and 3.89 g/g and 4.86 g/g for two D. rotundata cultivars (Omolokun and Abuja) and 4.05 g/g and 6.63 g/g for two D. alata cultivars (Tda 98/01166 and Tda92-2) by (Jimoh *et al.,* 2009). The swelling power of flour samples is often related to their protein and starch contents. Higher protein content in flour may cause the starch granules to be embedded within a stiff protein matrix, which subsequently limits the access of the starch to water and restricts the swelling power (Jimoh *et al.,* 2009). Flours lower in protein and higher in total starch content have a higher swelling ability. In addition to protein content, a higher concentration of phosphorous may increase hydration and swelling power by weakening the extent of bonding within the crystalline domain (Aprianita, 2009). A low swelling power was observed in cultivar *anumber* cultivar (2.45±0.85 g/ml) this could be due to stronger bonding force in its starch granules (Jimoh *et al*. 2009

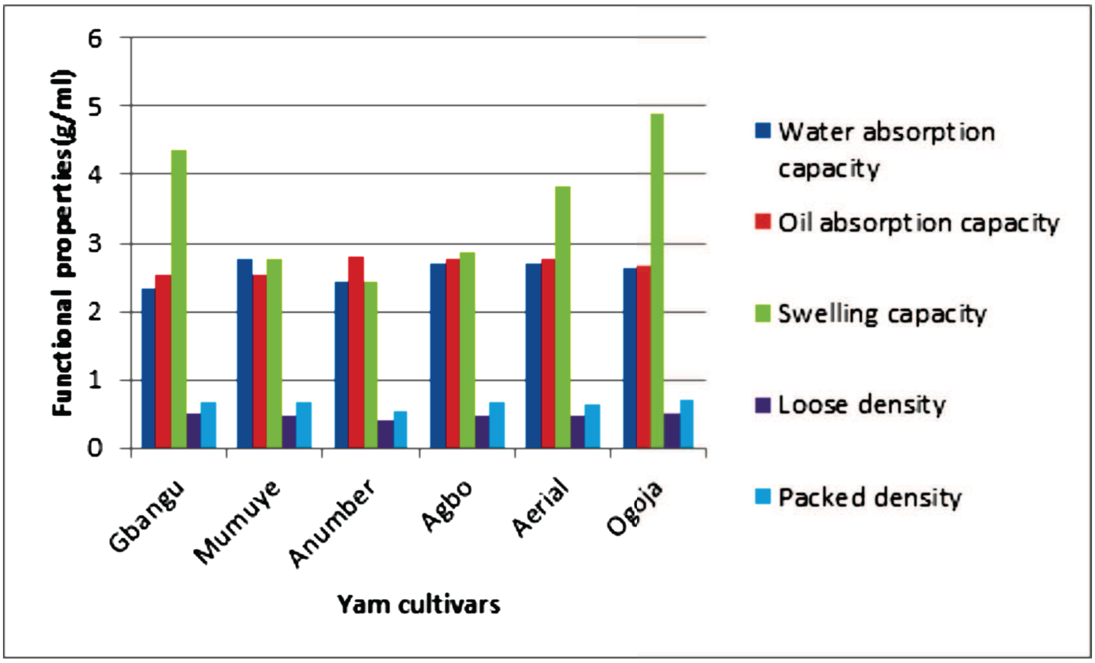

Figure 3: Functional properties of yam cultivars

Water absorption capacity of yam flours ranges from (2.32 ± 0.14-2.76 ±0.18g/ml). However, a lower water absorption capacity was observed in *gbangu* cultivar (2.32±0.14g/ml). Low water absorption capacity is attributed to a close association of starch polymers in the native granules. It may also be due to the dissociation of protein subunits (Jimoh *et al.,* 2009). For *cultivar abgo* (2.71±0.18g/ml), the observed variation in water absorption capacity may be due to change induced by the drying method.

Water absorption capacity of flour is a useful indicator of whether protein can be incorporated with the aqueous food formulations, especially, those involving dough handing (Appiah *et al*., 2010). Interactions of protein with water, is important to properties such as hydration, swelling power solubility, and gelation (Udensi *et al*, 2008). The high water absorption capacity of the flours from cultivar mumuye (2.76±0.18) suggests they could be useful in soup formulations (Appiah *et al*., 2010). The water absorption capacity describes water association ability under limited water supply and is an important functional property required in food formulations, especially those involving dough handling such as yam (Udensi *et al*, 2008).

The oil absorption capacity of yam flour ranges from 2.54 ± 0.08-2.79±0.05 g/ml. The lower oil absorption capacity of yam flour from cultivar *mumuye* (2.54±0.02) might be due to low hydrophobic proteins which show superior binding of lipids (Oladele, 2007).

The oil absorption capacity observed for the cultivars were higher than that the one 1.9 g g-1 reported by Ukpabi (2010). The high oil absorption capacity of the flours from cultivar *anumber* (2.79±0.05) may be due to the fact that flours had low oil content and high hydrophobic proteins which show superior binding of lipids (Kinsella, 1999).

According to *Appiah et al* (2010) lipid binding is dependent on the surface availability of hydrophobic amino acids. Oil absorption capacity is important as oil acts as flavor retainer and gives soft texture to food improving mouth-feel.

The emulsion stability of yam flours ranges from 40.29±2.58-55.77±0.91%. Lower emulsion stability of yam from cultivar *anumber* (43.67±0.87%) and aerial yam (40.29±2.58%) might be due protein being the surface active agents can form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Appiah *et al.* 2012). The emulsion stability of yam flours observed were higher than the one 41.49 and 44.69% reported by (Oladele, 2007). Emulsion stability can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation (Jimoh, 2009).

The results of foaming stability of different cultivars of yam flours ranges from (10.11 ± 1.28-24.04±1.36,7.5±1.25-22.08±1.45,5.00 ±2.36-20.00±1.54, (ml/g)(Fig 4). It was reported that formability is related to the rate of decrease of the surface tension of the air/water interface caused by absorption of protein molecules (Sathe *et al*., 1999).

Low foamability of cultivar aerial yam related to highly order globular proteins, which resists surface denaturation (Kaur *et al*., 2006). The basic requirements of proteins as good foaming agents are the ability to absorb rapidly at air water interface during bubbling, undergo rapid conformational change and rearrangement at the interface, and form a cohesive viscoelastic film via intermolecular interactions. The first two factors are essential for better foamability whereas the third is important for the stability of the foam. The success of whipping agents largely depends on how long the whip can be maintained (Kaur *et al*., 2006)

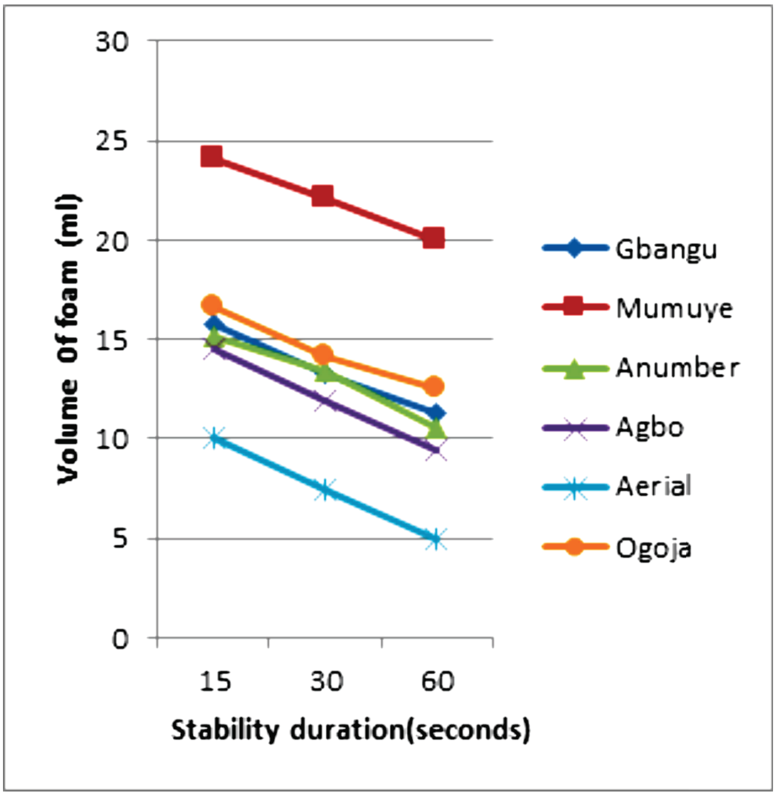

Fig.4.: Foam stability of yam cultivar flour

Conclusion

The research has shown that *mumuye, ogoja, gbangu and agbo* could best be used for food products that require molding (pounding, dough) such as porridge/pounded yam, noodle, and pastries, while cultivars *gbangu* and *anumber,* have greater potentials for discrete or particulate products (chips, frying, or boiling). The research further unveiled the phytochemical and anti-nutrient factors inherent in aerial yam that need proper pretreatment before usage. These are important information for both processors in selecting appropriate cultivars for their products and breeders in terms of food diversification and tuber quality improvement for specific uses.

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