PHYSICO-CHEMICAL PROPERTIES OF STARCHES FROM TWO VARIETIES OF SWEET POTATO AND YAM TUBERS AVAILABLE IN NIGERIA.

ABSTRACT

The research sought to investigate the functional properties of starches obtained from four Nigerian root and tubers, yam and sweet potato varieties, in order to facilitate their exploitation as substitute excipients for the local food and pharmaceutical manufacturing industry. The varieties, namely: white yam (*Dioscorea rotundata*), water yam (*Dioscorea alorta)*, orange flesh sweet potato (*Ipomoea batatas*) and cream flesh sweet potato (*Ipomoea batatas*), their respective starches were obtained by wet separation techniques and were analyzed for their pasting properties, physic-chemical properties, starch yield on dry and wet basis, functional, starch purity, amylase and amylo-pectin were undertaken in order to determine their suitability for food and other uses. The peak time, pasting temperature, peak viscosity, holding strength, breakdown, set from peak and set back from through ranged from 7.3 – 8.3 mins, 65.4 – 71.3 ^{o}C, 511.5 – 1001.2 BU, 860.8 – 871.3 BU, 300.1 – 306.9 BU, 240.8 – 248.1 BU and 400.4 – 510.9 BU respectively. There were significant differences ($p<0.05$) in the pasting properties. The crude protein, crude fat, crude fibre, ash, moisture and carbohydrate ranged from 1.55 – 1.85 %, 0.09 – 0.12 %, 0.12 – 0.22 %, 1.32 – 2.05 %, 10.72 – 11.09 % and 85.59 – 86.20 % respectively. There were significant differences ($p<0.05$) in the proximate composition of the starches. The starch yield on dry weight basis, starch weight on fresh weight basis, starch yield from tubers and percentage dry matter ranged from 56.84 – 85.88 %, 22.75 – 36.07 %, 18.02 – 26.00 % and 40.02 – 44.01 % respectively. There were significant differences ($p<0.05$) in the all the parameters. The bulk density, water absorption capacity, oil absorption capacity, gelatinization temperature, starch purity, amylase, amylo-pectin and pH ranged from 0.56 – 0.61 g/cm^{3}, 86.8 – 99.4 %, 103.2 – 125.4 %, 59.78 – 60.42 ^{o}C, 95.28 – 96.55 %, 27.25 – 29.37 %, 70.63 – 72.63 % and 6.82 – 6.91 respectively. There were significant differences ($p<0.05$) in all the parameters but no significant difference ($p>0.05$) in the pH. The starches from yam and sweet potato varieties starches can be exploited for diverse uses based on their different characteristics.

Key: water yam, white yam, orange flesh sweet potato; cream flesh sweet potato.

1. INTRODUCTION

Starch has always been an important item in the human diet. Except for its nutritional value, starch is usually added to foods as thickener, binder, adhesive, gelling agent, encapsulating agent, film former, stabilizer, texturizer, fat-replacer, or processing aid. Due to the sub-optimal behavior of native starch, modification of starch is the efficient way to provide starch products with suitable properties to meet the needs for specific uses [1]. Starches or their derivatives can be used in food as a major ingredient or as an additive to optimize processing efficiency, product quality or shelf life. In food industry, the application of starches or starch derivatives is in bakery products, desserts, confectionery, puddings, jams, soups, sauces, dressings, beverages, meat products, dairy products, and coating. The proper selection depends on the behavioral characteristics and the cost of the starch (derivative) with respect to the achieved application goal [2].

Tubers and roots are important sources of carbohydrates as an energy source and are used as staple foods in tropical and sub tropical countries [3]. These products have nutritionally beneficial components, such as a resistant starch and mucilage. Resistant starch has been attributed with a slow digestion in the lower parts of the human gastrointestinal tract which results in the slow liberation and absorption of glucose and aids in the reduction of the risk of obesity, diabetes and other related diseases [3].

Also tubers and roots do not contain any gluten, which is an important factor when considering a carbohydrate source. Using tubers as a source of carbohydrate instead of gluten containing carbohydrates, may aid in a reduction in the incidence of celiac disease (CD) or other allergic reactions [4].

Sweet potato is a tuber of the herbaceous climbing plant (*Ipomea batatas)* known in Britain much earlier than the Irish potato. The flesh may be white, yellow or pink (if carotene is present) and its leaves are also edible [5]. Sweet potato is another of the world's most important food crops and an important staple in Nigeria and other developing countries [6]. It is a low input crop and is used as vegetable, a desert, a source of starch and animal feed [6]. The orange-fleshed sweet potato (OFSP) varieties are rich in β-carotene, the major precursor of vitamin A. This biofortified variety was developed using conventional breeding practices drawing on sweet potato rich genetic diversity. The orange colour of OFSP is indicative of the level of β-carotene present; the more intense the colour, the more vitamin A present [7].
Water yam (*Discorea alata*) is a food crop with potential for partial replacement of wheat in bread making. Water yam flour can serve as a source of energy and nutrients (carbohydrates, beta-carotene and minerals) and can provide dietary fiber to processed food products. Addition of various proportions of water yam flour to wheat flour can enhance its nutritive values in terms of fiber and bioactive compounds such as resistant starches, dioscorine, diosgenin and a water soluble polysaccharides [8].Yams (*Dioscorea* spp.) are annual or perennial climbing plants with underground tubers that are suitable for eating. Yams are of great economic importance and nourishment to the people of Africa, the Caribbean, Asia and America [9].
This present study was aimed to assess the physic-chemical and functional properties of the main components of some starchy tubers commercially produced in Nigeria, with a view to finding their applications within the food industry. The tubers assessed in this study were orange and creamy flesh sweet potatoes, white yam and water yam. These tubers were sourced from Kaura Namoda of Zamfara, Kaduna, Benue and Shendam of Plateau State of Nigeria from local producers.

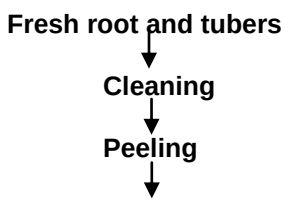
2. MATERIALS AND METHODS

2.1 Source of Raw Materials

Four root and tubers, white yam (*Dioscorea rotundata)* and water yam (*Dioscorea alata)* were obtained from two farmers in Garklang village, Derteng District of Shendam Local overnment in Plateau State. Nigeria, while the cream sweet potato (*Ipomoea batatas*) was purchased from Kaura Nomoda market in Zamfara State and orange flesh sweet potato (*Ipomoea batatas*) was obtained from a farmer at Kaduna State.

2.2. Starch Extraction

Starch was extracted from freshly harvested yam and sweet potato by wet extraction method described by Ellis [10] with modifications. The yams and sweet potato varieties were first sorted out and then peeled with knife. The peeled yam and sweet potato were washed with tap water to remove all dirt and cut into chunks of about 3-4 g. One kilogram of the chunks were weighed and ground with 500 ml of distilled water using the Waring Blender (Model MCBL2999, PRC). The slurry obtained was pressed through clean cheese cloth. The solids retained by the cloth were mixed with 1500 ml of distilled water and the resulting slurry pressed through clean cheese cloth. This process was repeated until there was little or no starch in the residue. Starch in filtrate was allowed to sediment for 3 hrs after which the supernatant was decanted and discarded. The starch was re-suspended in 500 ml of distilled water and the sedimentation and decanting steps repeated without pressing through cheese cloth. The starch was dried using oven (Model KF1010 AUD, Italy) at 60 ^{o}C for 6 hrs. The dried starch was ground into powder using a Waring Blender (Model MCBL2999, PRC) and then stored in low density polyethylene zip-lock bags prior to use.



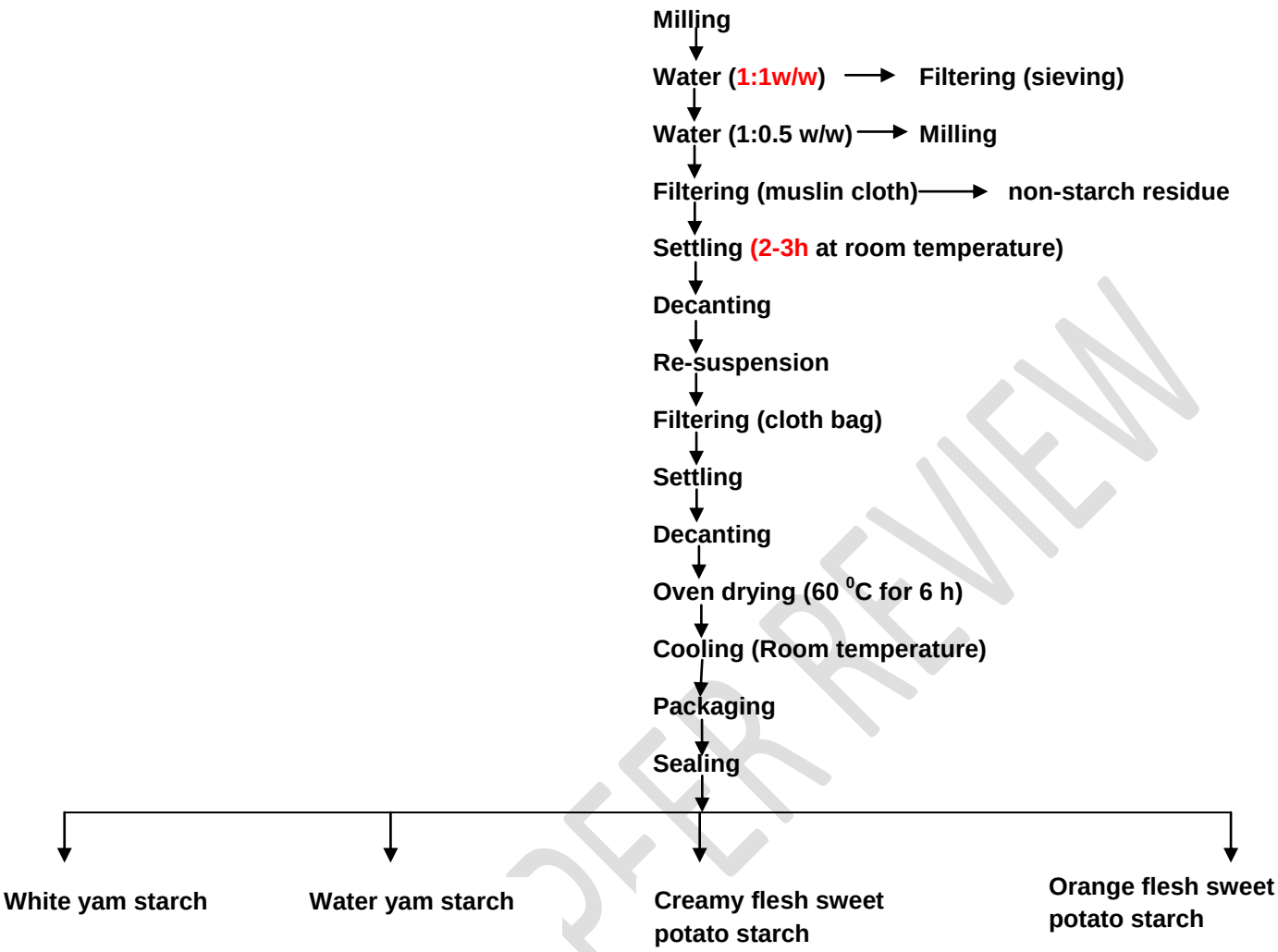


Fig 1. Flow process of starch production for root and tubers
Source: Ellis [10] with modification

2.3 Tuber dry matter

The sweet potato root tubers were washed with tap water and cut into small pieces (about 0.5 cm^2). Two sub-samples of 100 g each were dried in a hot air oven at 105 ^oC until constant weight. The dry matter content was estimated from the relationship:

$$\% \text{ Dry matter} = \frac{\text{Dry weight}}{\text{Fresh Weight}} \times 100$$

2.4.1 Starch yield on fresh weight basis (fwb)

The starch yield on fresh weight basis was calculated as a ratio of weight of starch (g) to weight of fresh root tubers (g) taking 14% as standard moisture content as follows:

2.4.2 Percent (%) Starch yield from fresh root tubers = $\frac{\text{Weight of dried starch}}{\text{Weight of peeled tubers}} \times 100$

2.4.3 Starch yield on fwb = $\frac{(14)\times(\%\ \text{starch yield from fresh root tubers})\text{Weight of dried starch}}{\text{Moisture content of dried starch}}$

2.4.4 Starch yield on dwb = $\frac{\text{Starch yield on fwb}}{\%\ \text{Dry matter}} \times 100$

2.4.5 Starch purity

The purity of starch extracted from the sweet potato root tubers was estimated using the relation:

(%) Starch purity = $\frac{\%\ \text{Carbohydrate}}{100 - \%\ \text{Moisture}} \times 100$

2.5 Determination of functional properties of the starch

2.5.1 Bulk density

A 50 g the starch sample was weight into a 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/cm^3) was calculated as weight of starch (g) divided by flour volume (cm^3) method described by Onwuka [11].

2.5.2 Gelatinization

Gelatinization temperature was determined by Onwuka [11]. 1 g of starch sample was weighed accurately in triplicate and transferred to 20 ml screw capped tubes. 10 ml of water was added to each sample. The samples were heated slowly in a water bath until they formed a solid gel. At complete gel formation, the respective temperature was measured and taken as gelatinization temperature.

2.5.3 Water and Oil absorption capacity

Water and oil absorption capacities of the starch samples were determined by Onwuka [11] methods. One gram of the starch was mixed with 10 ml of water/oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2ºC) for 1 h. It was then centrifuged at 200 x g for 30 min. The volume of water or oil on the sediment water measured. Water and oil absorption capacities were calculated as ml of water or oil absorbed per gram of starch.

2.6. Determination of proximate composition of the starch samples.

2.6.1 Moisture Determination

Moisture content was determined using the air oven dry method of AOAC [12]. A clean dish with a lid was dried in an oven at 100°C for 30min. It was cooled in desiccators and weighed. Two (2) grams of sample was then weighed into the dish. The dish with its content was then put in the oven at 105°C and dried to a fairly constant weight. The loss in weight from the original sample (before heating) was reported as percentage moisture.

$$\%\ Moisture = \frac{weight\ loss\ (W2 - W3)}{Weight\ of\ Sample\ (W2 - W1)}\ x\ 100$$

Where: W_1 = weight of dish, W_2 = weight of dish + sample before drying, W_3 = weight of dish + sample after drying.

2.6.2 Crude Protein Determination

The Kjeldahl method as described by AOAC [12] was used to determine the percentage crude protein. Two (2 g) of sample was weighed into a Kjeldahl digestion flask using a digital weighing balance (3000g x 0.01g 6.6LB). A catalyst mixture weighing 0.88g (96% anhydrous sodium sulphate, 3.5% copper sulphate and 0.5% selenium dioxide) was added followed by the addition of Concentrated sulphuric acid (7 ml) was added and swirled to mix content. The Kjeldahl flask was heated gently in an inclined position in the fume chamber until no particles of the sample was adhered to the side of flask. The solution was heated more strongly to make the liquid boil with intermittent shaking of the flask until clear solution was obtained. The solution was allowed to cool and diluted to 25 ml with distilled water in a volumetric flask. Ten (10 ml) of diluted digest was transferred into a steam distillation apparatus. The digest was made alkaline with 8 ml of 40 % NaOH. To the receiving flask, 5 ml of 2 % boric acid solution was added and 3 drops of mixed indicator was dropped. The distillation apparatus was connected to the receiving flask with the delivery tube dipped into the 100 ml conical flask and titrated with 0.01 HCl. A blank titration was done. The percentage nitrogen was calculated from the formula:

$$\%\ Nitrogen = \frac{(S-B)\times 0.0014\times 100\times D}{sample\ \ weig\,ht}$$

Where, S = sample titre, B = Blank titre, S - B = Corrected titre, D = Diluted factor

% Crude Protein = % Nitrogenx 6.25 (correction factor).

2.6.3 Crude Fat Determination

Fat was determined using Soxhlet method as described by AOAC [12].Samples were weighed into a thimble and loose plug fat free cotton wool was fitted into the top of the thimble with its content inserted into the bottom extractor of the Soxhlet apparatus. Flat bottom flask (250 ml) of known weight containing 150 – 200 ml of 40 – 60°C hexane was fitted to the extractor. The apparatus was heated and fat extracted for 8h. The solvent was recovered and the flask (containing oil and solvent mixture) was transferred into a hot air oven at 105^{o}C for 1 h to remove the residual moisture and to evaporate the solvent. It was later transferred into desiccator to cool for 15 min before weighing. Percentage fat content was calculated as

$$\%\ Crude\ Fat = \frac{weight\ of\ extracted\ fat}{Weight\ of\ Sample}\ x\ 100$$

2.6.4 Crude Fibre Determination

The method described by AOAC [12] was used for fibre determination. Two (2) grams of the sample was extracted using Diethyl ether. This was digested and filtered through the california Buchner system. The resulting residue was dried at 130 ± 2^{o}C for 2 h, cooled in a dessicator and weighed. The residue was then transferred in to a muffle furnace and ignited at 550^{o}C for 30 min, cooled and weighed. The percentage crude fibre content was calculated as:

$$\%\ Crude\ fibre\ = \frac{Loss\ in\ weight\ after\ incineration}{Weight\ of\ original\ food} \times 100$$

2.6.5 Ash Determination

The AOAC [12] method for determining ash content was used. Two (2) gram of sample was weighed into an ashing dish which had been pre-heated, cooled in a desiccator and weighed soon after reaching room temperature. The crucible and content was then heated in a muffle furnace at 550°C for 6-7 h. The dish was cooled in desiccator and weighed soon after reaching room temperature. The total ash was calculated as percentage of the original sample weight.

$$\% \, Ash = \frac{(W3 - W1)}{(W2 - W1)} \, x \, 100$$

Where:
W1 = Weight of empty crucible,
W_2 = Weight of crucible + sample before ashing,
W_3 = Weight of crucible + content after ashing.

2.6.6 Carbohydrate Determination

Carbohydrate content was determined by difference as follows:

$$\% \, Carbohydrate = 100 - (\%moisture + \%Protein + \%Fat + \%Ash \; + \; \%Fibre)$$

2.7 Determination of Amylose and amyo-pectin

The amylose content of the yam starch was determined based on the iodine colorimetric method of Williams [13] and Juliano [14]. About 0.1 g of the starch sample was solubilised with 1 ml of 95% ethanol and 9 ml of 1 N NaOH, and heated in a boiling water bath for 10 min; 1 ml of the extract was made up to 10 ml with distilled water. To 0.5 ml of the diluted extract was added 0.1 ml I N acetic acid and 0.2 ml iodine solution (0.2 g I2+2.0 g KI in 100 ml of distilled water) to develop a dark blue colour. The coloured solution was made up to 10 ml with distilled water and allowed to stand for 20 min for complete colour development. The solution was vortexed and its absorbance was read on a spectrophotometer at 620 nm. Absorbance of standard corn amylose with known amylose concentration was used to estimate the amylose content.

$$\boldsymbol{Amylose} \; = \frac{Absorbance \; of \; supernatant}{Absorbance \; of \; Total \; starc \; aliquot} \times Dilution \; factor \; \times 100$$

$$\boldsymbol{Amylopectin} \; \% = 100\% - \% \; Amylose$$

2.7.1 pH

Five grams of yam starch was weighed and mixed with 50 ml of distilled water to obtain slurry. The pH was then determined using a Fisher Science Education pH meter (Model G90526, Singapore) meter by inserting the pH probe into the slurry.

2.8 Starch purity

The purity of starch extracted from white yam, water yam, orange flesh sweet potato and cream flesh sweet potato root tubers were estimated using the relation below as described by the method of :

(%) Starch Purity = $\%$ Starch purity $= \frac{(\%\text{ Carbohydrate }\;)}{(100 - \%\text{ Moisture }\;)} \, x \, 100$

2.9 Determination of Pasting Properties

Pasting properties was carried out according to the method described by Addy [15] with modification. A smooth paste was made from the extracted starches (40 g) in 420 ml distilled water (8.8% slurry) for viscoelastic properties using Brabender Visco-amylograph (Viskograph-E, Brabender Instrument Inc. Duisburg, Germany) equipped with a 1000 cmg sensitivity cartridge. The smooth paste was heated at a rate of 1.5°C min-1 to 95°C and maintained for 15 min. Viscosity profile indices were recorded for pasting temperature, peak temperature, peak viscosity, viscosity at 95°C, viscosity after 15 min hold at 95°C (95°C Hold or Hot Paste Viscosity), viscosity at 60°C, viscosity after 15 min hold at 60°C (60°C Hold or Cold Paste Viscosity), breakdown and setback as described by Peroni *et al*. [16] with modifications.

2.10 Statistical Analysis

The Data obtained was subjected to analysis of,variance (ANOVA) and means separated by Fisher's least significant difference test using Genstat statistical package, version 17.0.

3. RESULTS AND DISCUSSION

Table 1. Pasting characteristics of the starches

Pasting characteristics	WAY	WYB	OFS	CFS	LSD
Peak Time	7.4±1.75^{c}	7.3±0.00^{d}	8.3±0.09^{a}	7.8±1.00^{b}	0.091
Pasting Temperature	71.3±0.01^{b}	70.7±0.03^{a}	65.4±0.00^{d}	69.0±0.05^{c}	2.316
Peak viscosity	523.1±11.62^{c}	511.5±23.42^{d}	987.6±21.65^{b}	1001.2±22.03^{a}	1.342
Holding strength	n.a	n.a	860.8±15.98^{b}	871.3±11.09^{a}	1.093
Break down	n.a	n.a	300.1±20.05^{b}	306.9±10.33^{a}	2.042
Set from peak	n.a	n.a	240.8±13.44^{b}	248.1±16.02^{a}	1.952
Set back from through	489.3±16.82^{c}	400.4±15.12^{d}	502.2±22.12^{b}	510.9±15.18^{a}	1.879

Values are means ± standard deviations of duplicate determinations. Means in the same row with different superscripts differ significantly ($p<0.05$).

Key: WYA= white yam (*Dioscorea rotundata*), WYB= water yam (*Dioscorea alata)*, OFS= orange flesh sweet potato, CFS= cream flesh sweet potato and LSD= least significant difference.

3.1 Pasting characteristics of the starches

The pasting properties illustrate the molecular changes and stages starch granules undergo when heated in excess water. They estimate starch water binding capacity and the strength of bonds in the starch granule. They can therefore be used to predict both binder and disintegrated quality. Starch pasting properties are known to be influenced by the amylose, lipid, protein and mineral content, as well as the granule size and size distribution [16].

Pasting properties are important functional characteristics of starches. When an aqueous suspension of starch is heated above a critical temperature, granules swell irreversibly and amylose leaches out into the aqueous phase, resulting into increased viscosity (pasting) starches processed from white yam, water yam, orange flesh and cream flesh sweet potato varieties are presented in Table 1.

There was a significantly different ($p<0.05$) in starches, It can also be observed from the results that the higher the pasting temperature, the longer the pasting time. The orange and cream flesh sweet potato had the higher pasting times (7.8 and 8.3 min) and lower pasting temperatures (65.4 and 69.0°C) respectively and therefore may be most appropriate for the production of foods that require shorter processing time.

The pasting temperature provides an indication of the minimum temperature required for sample cooking, energy cost involved and other components stability [17]. It also gives an indication of the gelatinization time during processing [17]. The pasting temperatures of the tubers varied significantly at ($p<0.05$). The pasting temperatures of the starches ranged from 65.4 - 71.3°C with orange flesh sweet potato having the lowest and white yam the highest.

Peak viscosity is a measure of the ability of starch to form a paste. It is also the ability of starch to swell freely before their physical breakdown [18]. Peak viscosity has been reported to be closely associated with the degree of starch damage. Peak viscosities of starches varied significantly at ($p<0.05$) and ranged from 511.5 – 1001.2 BU, this findings does not agree with Aprianita [4] reported that sweet potato had peak viscosity of 1238 BU and this could be due to its high starch (84.15%) content as well. Cream flesh sweet potato had the highest peak viscosity of 1001.2 BU whiles water yam had the lowest 511.5 BU. The high peak viscosity observed in cream flesh sweet potato implies that it may be suitable for products requiring high gel strength, thick paste. High peak viscosity is an indication of high starch content [19].

Holding strength measures the ability of starch to remain undisrupted when starch paste is subjected to a long duration of high, constant temperature during the process of steaming [20]. After a 15 min hold at 95°C, viscosities the holding strength observed ranged from 680.8 – 871.3 BU. High amylose starches have been found to re-associate more readily than high amylo-pectin starches. This is because the linear chains can orient parallel to each other, moving close enough together to bond [19].

Breakdown measures the ability of starch to withstand collapse during cooling or the degree of disintegration of granules or paste stability [19]. Adebowale [21] reported that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. Significant differences existed in breakdown viscosities of yam starches. The break down ranged from 300.1 – 306.9 BU. From this research, starch from cream flesh sweet potato had the highest ability to withstand heating during cooking.

Setback measures the re-association of starch [20]. Kin [22] reported that a high setback value is associated with a cohesive paste while a low value is an indication of a non-cohesive paste. Significant differences were observed in yam starches at ($p<0.05$). Setback values ranged from 400.4 – 510.9 BU. Low setback values are useful for products like weaning foods, which require low viscosity and paste stability at low temperatures [23], this findings is in agreement with [4].

Table 2. Proximate composition of Starches

Sample	Crude protein	Crude fat	Crude fibre	Ash	Moisture	Carbohydrate
WAY	1.55 ± 0.00^{d}	0.09 ± 0.00^{b}	0.12 ± 0.02^{b}	1.32 ± 0.02^{d}	10.72 ± 0.01^{b}	86.20 ± 0.06^{a}
WYB	1.65 ± 0.01^{c}	0.09 ± 0.00^{b}	0.16 ± 0.00^{b}	1.42 ± 0.00^{c}	11.09 ± 0.01^{a}	85.59 ± 0.01^{a}
OFS	1.78 ± 0.01^{b}	0.10 ± 0.1^{a}	0.15 ± 0.05^{b}	1.99 ± 0.01^{b}	10.11 ± 0.02^{c}	85.87 ± 0.07^{a}
CFS	1.85 ± 0.03^{a}	0.12 ± 0.01^{a}	0.22 ± 0.01^{a}	2.05 ± 0.01^{b}	10.09 ± 0.04^{c}	85.67 ± 00^{a}
LSD	0.057	0.020	0.072	0.042	0.342	1.093

Values are means ± standard deviations of duplicate determinations. Means in the same column with different superscripts differ significantly ($p<0.05$).

Key: : WYA= white yam (*Dioscorea rotundata*), WYB= water yam (*Dioscorea alata)*, OFS= orange flesh sweet potato, CFS= cream flesh sweet potato and LSD= least significant difference.

3.2 Proximate composition of the starches

The protein content of the sweet starches ranged from (1.85 - 1.55 %) and was not significantly different ($p<0.05$) from each other, the cream flesh sweet potato had the highest protein content of 1.85 % and white yam having the lowest 1.55 %. High protein content can affect starch gelatinization in diverse ways depending on the degree of polymerization, ability to retain water and their interaction capacity with starch molecules and granule surface [24].

There was a significant difference ($p<0.05$) in lipid amongst the roots which ranged from (0.09 – 0.12 %), the sweet potato starches had higher lipid content (0.10 - 0.124 %) than the yam varieties starch (0.09 %), although differences among the varieties were not significant. Low starch lipid content is recommended as higher quantities form complexes with amylose to inhibit starch swelling and solubility; hence reduce disintegration effects [25]. High starch lipid content may also have adverse effects on its binder quality as it increases the hydrophobicity of the polymers (amylose and amylo-pectin) [26].

The crude fibre content ranged from (12 – 0.22 %), there was a significant difference ($p<0.05$) amongst the roots. The ash content of the sweet potato varieties starches investigated and the yam varieties starch were significantly different from each other and it ranged from (1.32 – 2.05 %). The ash content indicates amount of insoluble salts and complexes in starch. Presence of inorganic salts and ions of phosphorous, sodium, iodine and hydroxyl groups in starch have been reported to contribute significantly to starch granule swelling and gelatinization [27].
The moisture content of the starches ranged from (10.09 – 11.09 %), there was a significant difference ($p<0.05$) in the starches. The carbohydrate content ranged from (85.59 – 86.20 %), there was no significant difference ($p<0.05$) in the roots.

Table 3. Tuber dry matter and Yield on fresh and dry weight basis

Parameters /Samples	WAY	WYB	OFS	CFS	LSD
Weight of fresh tubers (g)	5000±0.00^{a}	5000±0.00^{a}	5000±0.00^{a}	5000±0.00^{a}	0.001
Dry weight (g)	2053±1.23^{c}	2001±2.06^{d}	2200±2.33^{a}	2121±2.11^{b}	0.945
Weight of peeled tubers (g)	3979±0.08^{d}	4001±0.05^{c}	4009±0.06^{b}	4011±0.09^{a}	1.079
Weight of dried starch (g)	942±0.02^{c}	721±0.01^{d}	1011±0.00^{b}	1039±0.07^{a}	1.215
Starch Yield on dry weight basis (%)	75.06±0.21c	56.84±0.04^{d}	79.32±0.01^{b}	85.88±0.01^{a}	0.123
Starch Yield on fresh weight basis (%)	30.82±0.02^{c}	22.75±0.02^{d}	34.90±0.01^{b}	36.07±0.04^{a}	0.086
Starch yield from tubers (%)	23.60±0.01^{c}	18.02±0.02^{d}	25.22±0.00^{b}	26.00±0.03^{a}	0.011
% dry matter	41.06±0.01^{c}	40.02±0.01^{d}	44.01±0.03^{a}	42.02±0.02^{b}	0.010

Values are means ± standard deviations of duplicate determinations. Means in the same row with different superscripts differ significantly ($p<0.05$).
Key: WYA= white yam (*Dioscorea rotundata*), WYB= water yam (*Dioscorea alata)*, OFS= orange flesh sweet potato, CFS= cream flesh sweet potato and LSD= least significant difference.

3.3 Tuber dry matter and starch yield

All the four root and tubers varieties had high dry matter content ranging between (41.06 - 44.01 %), there was a significant difference ($p<0.05$) amongst the tuber. There are positive correlation between tuber dry matter content and starch yield [28]. However, the correlation observed in this study was not significant. Starch yield is known to be affected by not only the crop variety, but also the degree of association of granules with fibre and the method of extraction [32]. The starch yield on the fresh weight basis of the root and tubers ranged from (22.75 – 36.07 %) while the starch yield on the dry weight basis ranged from (56.84 – 85.88 %), there was a significant difference ($p<0.05$) on both the starches yield on dry and fresh weight basis. In addition, starch yield greater than 70 % on dry weight basis is deemed to be good enough for the industry [28].

Table 4. Some functional, starch purity, amylose and amylo-pectin properties of the starches

Samples	WAY	WYB	OFS	CFS	LSD
Bulk density (g/ml)	0.56±0.01^{d}	0.58±0.01^{c}	0.60±0.00^{b}	0.61±0.01^{a}	0.013
Water absorption capacity (%)	86.8±0.01^{d}	91.5±0.01^{c}	98.3±0.02^{b}	99.4±0.02^{a}	0.041
Oil absorption capacity (%)	103.2±0.00^{d}	110.0±0.00^{c}	121.2±0.01^{b}	125.4±0.01^{a}	1.021
Gelatinization temperature (^{o}C)	59.78±0.01^{c}	59.98±0.02^{c}	60.00±0.00^{b}	60.42±0.01^{a}	0.035
Starch purity (%)	96.55±0.02^{a}	96.27±0.04^{b}	95.28±0.01^{c}	95.29±0.00^{c}	0.089
Amylose (%)	28.44±0.01^{b}	29.37±0.01^{a}	27.37±0.02^{c}	27.25±0.01^{c}	1.011
Amylopectin (%)	71.56±0.02^{b}	70.63±0.^{02b}	72.63±0.01^{a}	72.75±0.00^{a}	1.122
pH	6.82±0.01^{a}	6.88±0.01a	6.91±0.01^{a}	6.89±0.01^{a}	0.165

Values are means ± standard deviations of duplicate determinations. Means in the same row with different superscripts differ significantly ($p<0.05$).

Key: WYA= white yam (*Dioscorea rotundata*), WYB= water yam (*Dioscorea alata)*, OFS= orange flesh sweet potato, CFS= cream flesh sweet potato and LSD= least significant difference.

3.4 Functional, starch purity, amylose and amylo-pectin properties of the starches

The bulk properties describe the density, consolidation and flow of a powder mass [29]. The bulk density of starches ranged from 0.56 - 0.61 g/ml. There was a Significant differences ($p<0.05$) in the starches. The finding of this research are line with the results of Eric [30] with bulk density of sweet potato starch of (0.6 -0.78). Higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness; while low bulk density of starch is a good physical attribute when determining transportation and storability.

Water absorption capacity represents the ability of the products to associate with water under conditions when water is limiting such as dough's and pastes. There was a Significant differences ($p<0.05$) in the water absorption capacity of the starches, which ranged from 86.8 – 99.4 %, the lowest value of 86.8 % was observed in white yam (*Dioscorea rotundata*), while the highest value of 99.4 % in cream flesh sweet potato (*Ipomea batatas*). Water absorption of starch is dependent mainly on the amount and nature of the hydrophilic constituents and to some extent on pH and nature of the protein [31]. Water absorption characteristic represents the ability of the product to associate with water under conditions when water is limiting such as dough and pastes. The results of this study suggest that starches from orange flesh and cream flesh sweet potato and yam varieties would be useful in foods such as bakery products which require hydration to improve handling characteristics.

Oil absorption capacity is attributed mainly to the physical entrapment of oils. It is an indication of the rate at which protein binds to fat in food formulations [31]. The oil absorption capacity of the starches ranged from 103.2 – 125.4 %, the lowest value of 103.2 % was observed in white yam (*Dioscorea rotundata*), while the highest value of 125.4 % in cream flesh sweet potato (*Ipomea batatas*). Sweet potato starch having highest OAC could be therefore be better to yam starch as flavor retainer. The ability of the

proteins of these starches to bind with oil makes it useful in food system where optimum oil absorption is desired. This makes starches to have potential functional uses in foods.

The temperature at which gelatinization of starch take place is known as the gelatinization temperature. The gelatinization temperature ranged from 59.78 – 60.42 °C. Highest Gelatinization temperature was observed for cream flesh sweet potato starch 60.42 °C and lowest for white yam starch 59.78 °C as individual starch.

Amylose and amylo-pectin ratio is one of the parameters reported to contribute to good textural attributes of root and tuber crops [15]. There was a Significant differences ($p<0.05$) in the amylase content of the starches, which ranged from 27.25 – 29.37 %, respectively. Amongst these tubers orange flesh sweet potato has the least amylose content. The sweet potato starches however recorded significantly lower amylose content than the two varieties of yam. The general low content of amylose in samples indicates that when these starches are incorporated into food products, swelling of starch will be enhanced [15].

Amylo-pectin content ranged from 70.63 – 72.75 %. The results indicate a Significant differences ($p<0.05$) in the amylo-pectin of the starches. On the other hand, starch amylo-pectin is reported to enhance granule swelling as a result of repulsion between phosphate groups on adjacent amylo-pectin chains. The sweet potato starches having higher amylo-pectin ratio are therefore expected to exert stronger disintegrantion action compared to the two varieties of yam. The pH of tubers ranged from 6.82 – 6.91, there was no significant difference ($p>0.05$) in the pH of the starches

3.0 CONCLUSION

The high amylose content in starches may contribute to good textural attributes. Orange and cream flesh sweet potato starches may be used industrially for products that require high unit yield as well as production of weaning foods and production of noodles, since they have the ability to withstand heating and shear stress during cooking. Cream flesh sweet potato can be exploited for starch production because of its high starch yield. The extracted starch may be used in the food and other pharmaceutical industries or for food products that require thick paste, high gel strength and elasticity. Also the two varieties of the sweet potato may be used in substituting yam in the preparation of pounded yam. Starches from yam and sweet potato varieties can also serve as alternate sources of starch based on their unique characteristics and thus, can be used for diverse products.

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