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Morphology, Rheology and Functional Properties of Starch from Cassava, Sweet Potato and Cocoyam

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Authors' contributions

This work was carried out in collaboration between all authors. Author ACA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NTU and ACA managed the analyses of the study. Author ECF managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To produce starch from cassava variety varieties (30572, 419, and umu 37), sweet potato root (*x-igbariam*), cocoyam (*edeuhie* and NXS003). To study and compare their functional, pasting and micro-structural properties.
Study Design: Multifactor randomized complete block design (RCBD) was used for this study. Each experiment was repeated in duplicate. Data obtained were subjected to analysis of variance (ANOVA) at the significant level of 5% *($p \leq .05$)* using SPSS 20.
Place and Duration of Study: Department of food science and technology, Michael Okpara University of Agriculture, Umudike, between May 2016 and October 2016.
Methodology: A Total of 6 (six) starch samples were produced from cassava variety varieties (30572, 419, and umu 37), sweet potato root (*x-igbariam*), cocoyam (*edeuhie* and NXS003). The starch samples were analyzed for functional, pasting and micro-structural properties.

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Results: The starch from different tuber crops analysed showed different functional, pasting and micro-structural properties. At $p \leq .05$ significant level, Pasting temperature was highest in cocoyam starch sample (ede) while cassava starch sample 419 was the lowest. Peak, trough and breakdown result was highest in sweet potato starch while peak was lowest in Cocoyam starch sample. Solubility was highest in cocoyam (Ede) and lowest in cassava sample 419. The microscopic picture of starches showed spherical shape for all granules with cocoyam starch having smooth, fine and regular circle shape. Cassava starch sample 30572 was highest in granular size while 419 recorded lowest granular size.

Conclusion: Starch from different plants and varieties significantly differ in their functional, pasting and micro-structural properties. Different starch products require different physiological properties and when starch source is rightfully selected; different starch source shows optimum functionalities in specific product.

Keywords: Starch; microstructure; physiology; cassava; cocoyam sweet-potato.

1. INTRODUCTION

Tubers and roots are important sources of carbohydrates as an energy source and are used as staple foods in tropical and sub-tropical countries [1]. Starch granules are insoluble in cold water but swell reversibly to a limited extent through hydrogen bonding. With additional heat, the granules continue to swell. As the temperature is increased, the thermal energy overcomes the inter and intra-molecular hydrogen bonds and hydrophobic interactions, resulting in irreversible disintegration of granular order. In the gelatinization process, the point at which the native crystalline regions are melted, birefringence is lost [2]. Continued heating will result in a colloidal solution. Generally, the gelatinization of starch granules occurs over a temperature range that differs for each starch type. Examples include; normal maize, 64.4 to 80.4°C; waxy maize, 64.2 to 80.4°C; and normal potato, 59-68°C [3]. Gelatinization temperatures of starch are affected by granule size [4], degree of crystalline [5], relative amounts of amylose and amylopectin [6], presence of phosphorous derivatives [7], lipids (Morrison [8]) and the amylopectin branch-chain length [9]. Pasting follows gelatinization and was defined by Atwell et al. [10] as "the phenomenon following gelatinization in the dissolution of starch. It involves the granular swelling, extrudation of molecular components from the granule and eventually total disruption of the granules." In both food and industrial applications, pasting is an extremely important attribute of the functionality of starch. Starch pastes are extensively used as thickeners, stabilizers and binders. Paste viscosity of starch, as measured by Brabender Visco-amylograph or Rapid Visco Analzer, is often used as a critical acceptance measurement in quality control processes by both starch manufacturers and end-use industries. 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 cardiac disease (CD) or other allergic reactions. Selection and use of starches in food products require basic knowledge of food processing and starch properties [11]. Therefore, the study of starch and its molecular structures and functional relationships is important. The understanding of starch molecular structures gives direction to breeders, starch producers and processors. Today, there is growing interest in natural starches with unique properties for use in foods to avoid starch modified" label statement. Therefore, the present study was aimed to assess the Rheological, Microscopy and functional properties of starch from tubers, in an attempt to broaden what applications they may be used for within the food industry. The tuber starches assessed in this study were cassava (419 um37 and 30572) sweet potato (*x-igbariam)* and cocoyam (*edeuhie* and NX003).

2. MATERIALS AND METHODS

2.1 Source of Materials

Matured roots of four *Cassava* varieties (30572, 419, and umu 37), one sweet potato root (*x-igbariam*) and two cocoyam (*edeuhie* and NXS003) were obtained from National Root Crops Research Institute (NRCRI), Umudike and processed into starch within 24 hrs after harvest.

2.2 Processing of Starch

The method described in Osunsami et al. [12] with slight modification was used for the

production of starch from cassava, sweet potato and cocoyam samples. Matured roots of cassava (30572, 419 and umu 37) sweet potato (x-*lgbariam*) and cocoyam (*edeuhie* and NXS003) were peeled and washed with clean water and allowed to drain. They were subsequently grated with locally fabricated grater. The pulp was placed on a muslin cloth, sieved and flushed with clean water until the starch stream ceases. The crude starch milk was kept in a refrigerator overnight. The supernatant were decanted leaving the precipitated starch.

2.2.1 Purification of starch

Exactly 1000 mL of clean water was added to 300 g of crude starch and stirred until all the starch was suspended in the water. The suspension was undisturbed until sedimentation ceased. The supernatant was decanted leaving the sediments in a plastic bucket. An equivalent volume of fresh clean water was added to the volume of the starch sediments and stirred manually with manual stirrer until the starch was suspended in the water. The starch slurry was filtered through a muslin cloth and flushed with water. The filtrates were allowed to sediment for 20 min and the supernatant decanted. This procedure was repeated two (2) times yielding clean starch cake.

2.2.2 Quality control of the starch

Exactly 5 g sample was taken from the top of the clean starch cake sediment and dissolved in a 15 mL of water in a test tube. The tube and its content were centrifuged for 20 min at 2000 rpm and a small sample was drawn from the boundary between the liquid and the sediment using a pipette. Observation was done under a Microscope (Coslab HL-10, India) (magnification x400). Absence of particles in the samples under observation confirmed its purity.

2.2.3 Drying and storage

The starch flakes were spread on a table and allowed to sundry for two days. They were pulverized with a milling machine (Thomas Wiley mill-model Ed-5, Philadelphia, USA 1982), stored in bottles and preserved in a refrigerator (Haier thermacool, model HRF-350, 2001) [13].

2.2.4 Starch yield

Percentage starch was calculated on dry bases as

[{(Weight of ground tuber - weight of starch)/ Weight of ground tuber} x 100/1]

2.2.5 Rhelogical properties of starch

Paste viscosity/Rheology were determined using the Rapid Visco Analyser (RVA). Measuring the viscosity of cooked paste of starch based product. Starch (3 g) was dispersed in 25 ml distilled water and quantitatively mixed and transferred into the canister of RVA model 4500 (Perten Instrument, Sweden) as recommended. The slurry was heated from to 95°C with a holding time of 2 min. The rate of heating and cooling were at constant rate of 11.25°C per min. Peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature were read from the pasting profile with the aid of thermocyline for windows software connected to a computer [14]. The viscosity was expressed in terms of Rapid visco unit (RVU) which is equivalent of 10 centipoises.

2.2.6 Functional properties of starch

2.2.6.1 Water absorption capacity

The procedure of Sathe et al. [15] was used. Exactly 10 mL of water was added to 1 g of each sample. The suspension was then stirred for 5 min. The suspension was transferred into centrifuge tube (centrifuge 0151, Corning brand, United State) and centrifuged at 3,500 rpm for 30 min. The supernatant obtained was measured using 10 mL measuring cylinder. The density of water was assumed l g/mL. The water absorbed was calculated as the difference between the initial water used and the volume of the supernatant obtain after centrifuging. The result was expressed as a percentage of water absorbed by the starch on g/ml basis.

2.2.6.2 Oil absorption capacity

The procedure of Sathe et al. [15] was used as described above. Instead of water used, refined soybean oil with density of 0.92 g/mL was used. The oil and the starch blends (1.0 g starch in 10 mL oil) were mixed using a magnetic stirrer at 1,000 rpm for 5 min and then centrifuged at 3,500 rpm for 30 min. The amount of oil separated as supernatant was measured using 10 mL cylinder. The difference in volume was taken as the oil absorbed by the samples. The oil absorbed was expressed as g/mL of oil absorbed.

2.2.6.3 Swelling capacity

The methods describe by Safa-dedeh and Saalia [16] was used. About 1 g of the sample were

weighed into 10 ml graduated measuring cylinder and volume measured. The samples were mixed with water stirred and allowed to stand for 1 h. Increase in volume was measured in g/ml.

$$\text{Swelling index} = \frac{\text{final weight} - \text{initial weight}}{\text{weight of sample}} \times \frac{100}{1}$$

2.2.6.4 Solubility

The total solubility of the starch samples at room temperature was determined using the method of Singh [17]. Exactly 1 g of the sample was weighed into a centrifuge tube containing 10 mL distilled water. The mixture was stirred and allowed to stand for 1 h before being centrifuged at 4,000 rpm for 15 min. The supernatant was evaporated in a previously clean, weighed moisture can. The solubility was measured as increase in weight of the can over the weight of the sample and expressed in percentage.

2.2.6.5 Bulk density

The bulk density of the starch samples was done using the method of by AOAC [18]. Exactly 10 mL capacity graduated measuring cylinder was weighed and gently filled with the samples. The bottom of the cylinder was tapped several times until there was no further diminution of the sample level after filling to the 10 mL mark.

Calculation:

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

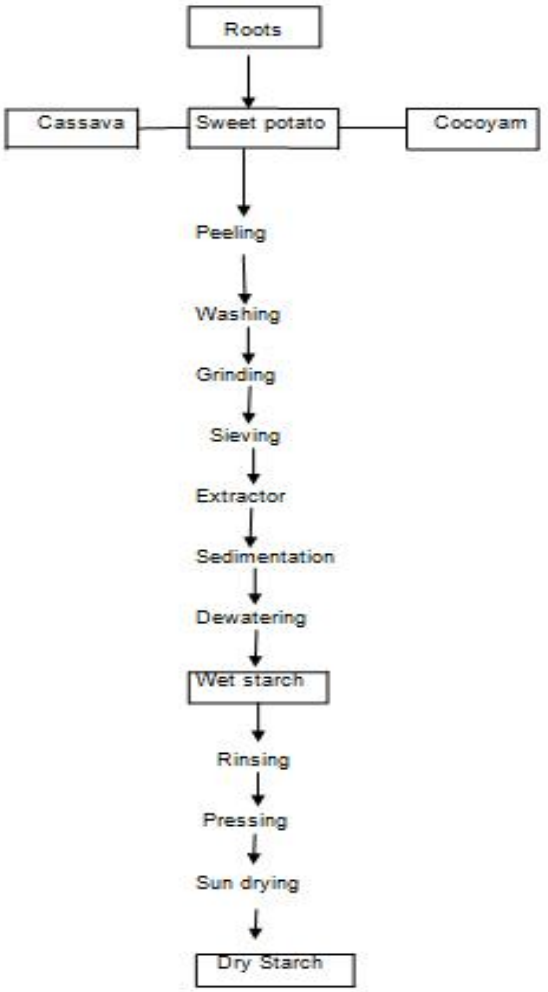

Fig. 1. Flow chart for production of starch from root crops

2.2.6.6 Starch granule morphology

Starch granule morphology of native starch from cassava, sweet potato and cocoyam were studied using scanning electron microscopy (SEM). One gram of dry starch was suspended in 10 mL of water at 25°C and gently stirred for 5 min. Starch samples were stained with crystal violate, mounted on circular aluminum stubs using adhesive and then coated with thin layer of gold using Bio-Rad Sputter coating System. The samples were examined and photographed in a Joel Scanning Microscope (JSM-6400, TOKYO, Japan). This was connected to a Microscope (coslab HL-10, India) at an accelerated voltage of 5 kv and magnification of X400. Twenty (20) granules were selected randomly and their size measured.

2.2.6.7 Gelatinization temperature

Exactly 10% starch dispersion was prepared in tube with distilled water. The suspension was mixed thoroughly and heated. The temperature at which the starch starts gelling is recorded as the gelatinization temperature (°C).

2.3 Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) at the significant level of 5% *(p≤ .05)* using SPSS 20 (analytical software). Statistical differences were found using least significant difference (LSD) at the 5% significant levels.

3. RESULTS AND DISCUSSION

3.1 Pasting Properties of Selected Root Crop Starches

Amylograph pasting viscosity studies on the starches in Table 1 showed pasting temperature ranged from 71.5 to 86.45°C. Cocoyam starch sample (ede) was highest while cassava starch sample 419 was the lowest in Pasting temperature. There were significant differences (p≤.05) among the samples analyzed. The lower pasting temperature, the better the gelling ability of starch. Pasting temperature is considered as a reflection of the degree or order arrangement of molecules in starch granules. Onset temperature is influenced by short amylopectin branch-chains and low Pasting temperature is characteristics of starches with large proportions of short amylopectin branch chains) [19]. Pasting temperature is an indication of granular architecture (crystalline quality) and high peak temperature might be due to higher proportion of longer chains in the amylopectins as these requires higher temperature to dissociate completely than required for shorter double helices [20]. Higher Pasting temperature for cocoyam starches that compared to cassava starches suggests the presence of higher proportions of long amylopectin chains in cocoyam starch [20]. Peak, trough and breakdown result was highest in sweet potato starch (pot = 630.33 RVU, 300.25 RVU and 330.09 RVU respectively) while peak was lowest in Cocoyam starch sample (ede = 305.05 RVU), cassava starch sample 419 was lowest for trough, (150.38 RVU) and break down (228.33 RVU). There were significant differences (p≤.05) among the starches analyzed. Ricard [21] reported a similar result saying that *Xanthosoma* starch has low viscosity values. Cocoyam is not susceptible to retrogradation and this makes it suitable source of carbohydrate in complementary food production [22]. The difference in pasting properties of starches are attributed to factors such as starch composition (amylose to amylopectin ratio, amount of lipid complex amylose chains, phosphorus content), molecular structure *e.g*., Amylopectin (unit chain and extent of branching and granular architecture (crystalline to amorphous ratio) [23]. Thickening and swelling are desired functionalities governing the use of starch in food production such as sauce. These two functionalities depend on pasting characteristics of starch [20].

3.2 Functional Properties of Starch from Cassava (419, UM37, 30572), Sweet Potato (*x-igbariam*) and Cocoyam (NXS003, *Edeuhie*)

3.2.1 Bulk density

From Table 2, the bulk density of the starches from cassava sample 419 was the highest (0.81 g/mL) and lowest (0.28 g/mL) in sweet potato starch samples, bulk density of starches analyzed were generally low. There were significant differences (p≤.05) among the samples in terms of bulk density. High bulk density limits caloric and nutrient intake which result in growth faltering [24]. Bulk density is affected by particle size and density of the sample [25].

Table 1. Pasting properties of starch from cassava (419, um37, 30572), sweet-potato (x-*igbariam*) and cocoyam (*edeuhie,* NXS003) tubers

Sample	Peak 1 (RVU)	Trough 1 (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (sec)	Pasting temperature (°C)
419	378.71^{c}	150.38^{e}	228.33^{d}	220.25^{d}	69.88^{b}	4.13^{b}	74.35^{d}
um37	430.38^{b}	155.42^{e}	274.96^{b}	224.21^{d}	68.79^{b}	3.70^{c}	71.50^{f}
30572	436.67^{b}	177.63^{c}	259.05^{c}	221.58^{d}	43.84^{d}	3.74^{c}	72.73^{e}
Pot	630.05^{a}	300.25^{a}	330.09^{a}	355.33^{a}	55.09^{c}	4.24c	78.33^{c}
NXS	343.54^{d}	183.63^{b}	137.42^{b}	291.33^{b}	107.71^{a}	4.60^{a}	84.93^{b}
Ede	305.05^{e}	166.04^{d}	139.00^{e}	277.05^{c}	111.00^{a}	4.67^{a}	86.45^{a}
LSD	0.054	0.073	0.782	0.198	0.148	0.063	1.00

Means with different superscript within the same column are significantly different (p≤.05) 419, um37 and 30572 are cassava starch, ede (edeuhie) and Nxs (Xanthosoma) are cocoyam starch, pot (x-Igbariam) is white skinned sweet potato, LSD is Least Significant Difference

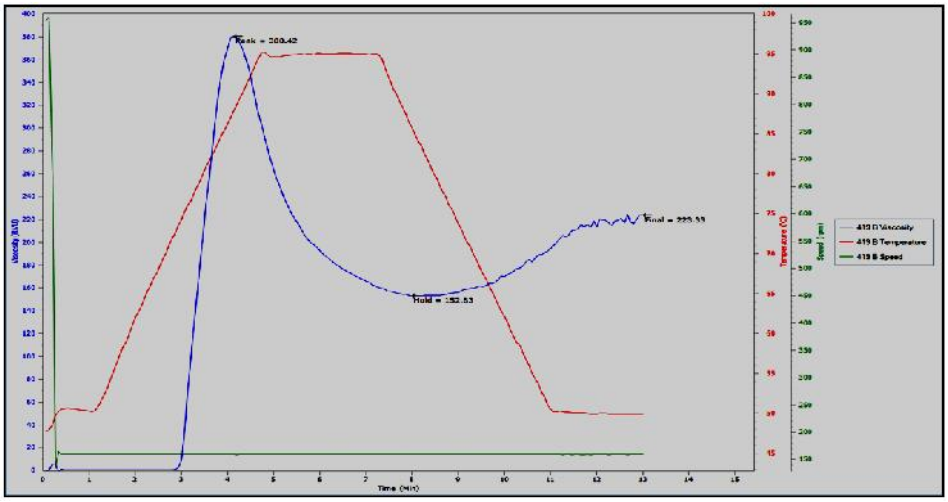

Fig. 2. Cassava 419 starch

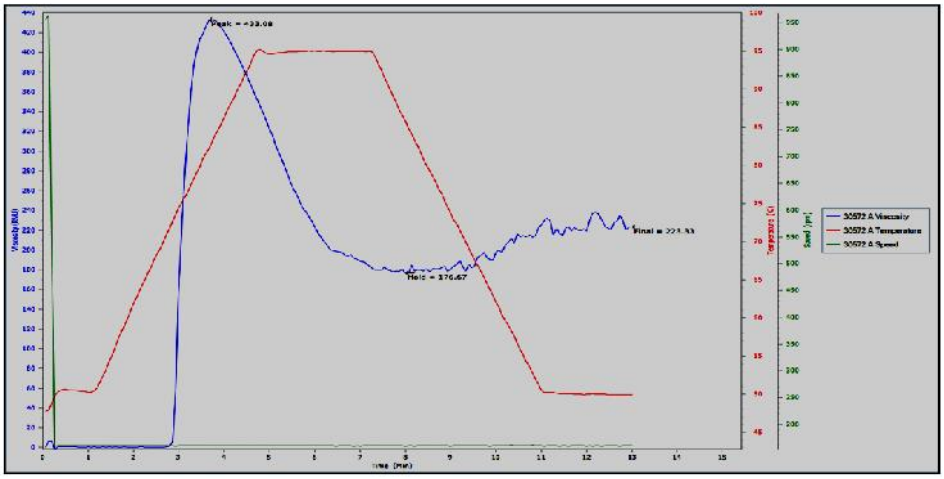

Fig. 3. Cassava 30572 starch

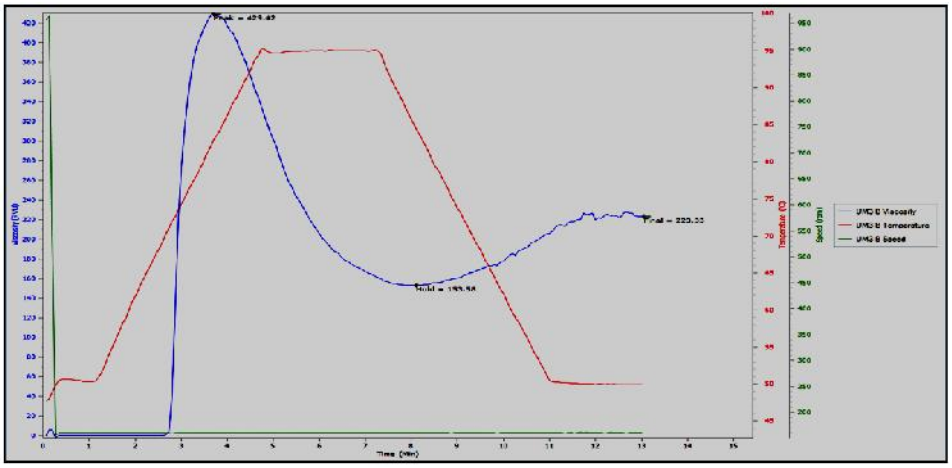

Fig. 4. Cassava um37 starch

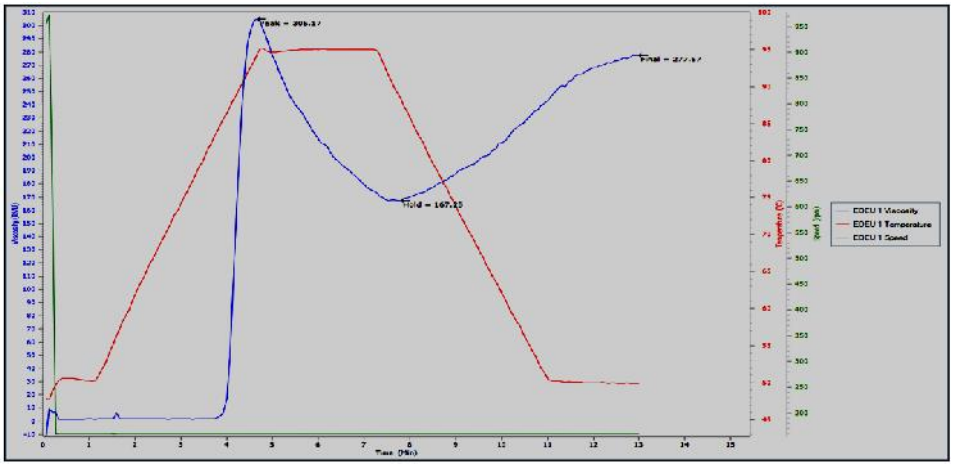

Fig. 5. Cocoyam *edeuhie* starch

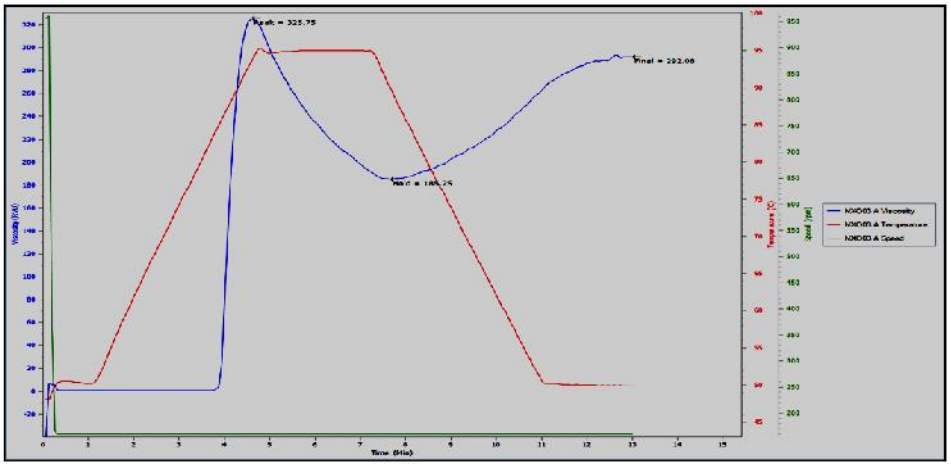

Fig. 6. Cocoyam NXS003 starch

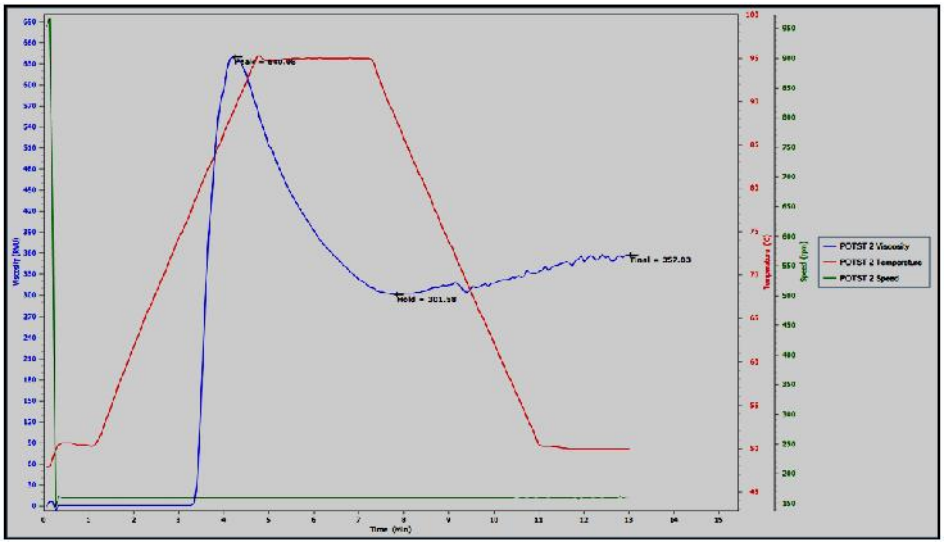

Fig. 7. Sweet potato (x-*igbariam*) starch

Plate 1. Rapid viscoamylo-graph of starch from cassava (419, um37, 30572), sweet potato (x-*igbariam*) and cocoyam (NXS003, *edeuhie*) tuber

Plaami [26] reported that bulk density is influenced by the structure of starch polymers and loose structure of starch results in low bulk density. Low bulk density observed in starch samples in the work is an advantage. Low bulk density gives an indication of the greater case of dispersibility and reduction of paste thickness [27]. Low bulk density is easily carried and distributed to locations where they are required [28].

3.2.2 Water absorption capacity (WAC)

Water absorption capacity result in Table 2 ranged from 150 for cassava sample 419 to 180 for cocoyam sample Nxs003. There were significant differences ($p \leq .05$) in WAC among the samples. Water absorption capacity is a useful indication of whether flour can be incorporated into aqueous food formulation, especially those involving dough handling [29]. Water absorption capacity is important in bulking and consistency of products as well as baking application [30]. Better water absorption capacity suggests better performance in texture [31]. Increase in water absorption capacity implies increase in digestibility of starches. The difference might depend on the amount and nature of hydrophilic constituent [32]. Water abortion capacity reveals the inter-molecular associations between starch polymers [33].

3.2.3 Oil absorption capacity

Oil absorption capacity of the starch samples were between 1.2 mL/g to 2.4 mL/g. Cassava starch sample 30572 was lowest while cocoyam starch sample NXS were the highest. There was significant difference ($p \leq .05$) among the samples in terms of oil absorption capacity. The ability of starch of these roots crops to bind with oil makes it useful in food system where optimum oil absorption is desired. The high oil absorption capacity suggests that cocoyam starch may contain more hydrophobic proteins than cassava and sweet potato. More hydrophobic proteins demonstrate superior binding of lipids [34].

3.2.4 Swelling index

Swelling index of starches in Table 2 ranged from 0.105 g/mL to 0.505 g/mL. cassava starch 419 was the lowest while sweet potato (pot) was the highest. There was significant difference ($p \leq .05$) among the starches analyzed in terms of swelling index.

Swelling index is an indication of the water absorption index of the granules [35] reported that the swelling index of the granules reflects the extent of associative force within the starch, the lower the association the lower the swelling power [36]. Swelling index of starch depend on the capacity of starch molecule through

hydrogen bonding [37]. High swelling index in sweet potato and cocoyam sample (NXS003) may be as a result of differences in the amylopectin content of the various starches since swelling index has been describes as amylopectin property [38,39] .

3.2.5 Solubility

The result of solubility in Table 2 recorded highest in cocoyam Ede (1.71 g/mL) and lowest in cassava sample 419 (1.5 g/mL). There were no significant differences in the solubility ($p \geq .05$) among the starch analyzed. Low fat content leads to increase in solubility. Kim and Wiesenborn [40] observed that increase in solubility was attributed to the low fat content and weak internal starches. Brambridge et al. [41] stated that good quality starch with high starch content and paste viscosity will have a low solubility, high swelling volume and swelling power. This was observed in this work. The difference in solubility and swelling power indicates difference in structure and solubility of starch and also could be attributed to difference in chain length/distributions in starches [42].

3.2.6 Gelatinization temperature

The result of gelatinization temperature in Table 2 ranged from 69.25 to 90.1°C. Cassava starch sample 30572 was lowest while sweet potato starch sample recorded highest gelatinization temperature. There was significant difference ($p \leq .05$) in the gelatinization temperature among the starch samples analyzed. Gelatinization affects digestible and texture of starch content of foods [43]. The gelatinization temperature gives an indication of the strength of associative force within the starch granules, so higher associative force leads to lower gelation temperature. Cassava starch samples showed lower gelaton temperature than cocoyam and sweet potato. This is in line with the works of Erikson et al. [44] reported lower gelatinization temperature for cassava starch which they translated into shorter cooking time than wheat flour.

3.3 Granules Size Distributionof Starch from Cassava (419, um37, 30572), Sweet Potato (x-*igbariam*) and Cocoyam (Nxs003, *Edeuhie*)

The result of granule size distribution are shown in Table 3. The granule size ranged from 27.3 um to 140 Nm. Cassava starch sample 30572 was highest in granular size (273Nm) while 419 recorded lowest granular size (140 Nm). Sweet potato starch was highest in terms of the size range (220-300 Nm). Sweet potato starch also showed a high particle size of 254 Nm.

The surface of the starch granules of samples analysed appeared to be smooth and fine with no evidence of fissures. This is because no treatment was given to the starch prior to analysis. The starches used for this study had a fine particle size distribution. Particle size affects the rates of hydration during processing as very fine (<180 Nm) particle size have greater tendency to absorb more water during hydration [45,46] reported that large particle requires time for water to incorporate and tend to form larger dough lumps. Tian et al. [47] suggested that small granules have higher

Table 2. Functional properties of starch from cassava (419, um37, 30572), sweet potato (X-*igbariam*) and cocoyam (Nxs003, *edeuhie*)

Sample	Bulk density (g/mL)	Swelling Index (g/mL)	Solubility (g/mL)	Gelatinization temperature(ºC)	Visual-gel color	WAC (g/mL)	OAC (g/mL)
419	0.81^{a}	0.105^{e}	1.50^{a}	72.5^{d}	Transparent	150.0^{c}	180.0^{b}
um37	0.43^{b}	0.200^{d}	1.68^{a}	67.15^{g}	Milky	160.0^{c}	160.0^{c}
30572	0.41^{b}	0.410^{b}	1.65^{a}	69.25^{e}	White	170.0^{b}	120.0^{e}
Pot	0.28^{c}	0.505^{a}	1.62^{a}	90.10^{a}	Golden	190.0^{a}	160.0^{c}
Nxs	0.71^{a}	0.325^{c}	1.62^{a}	85.05^{b}	Dirty brown	180.0^{a}	240.0^{a}
Ede	0.57^{b}	0.475^{ab}	1.71^{a}	83.25^{c}	Light purple	170.0^{b}	140.0^{d}
LSD	0.054	0.051	0.05	1.00		0.267	1.00

Means with different superscript within the same column are significantly different ($p \leq .05$) 419, um37 and 30572 are cassava starch, ede (edeuhie) and Nxs (Xanthosoma) are cocoyam starch, pot (x-Igbariam) is white skinned sweet potato, LSD is Least Significant Difference.WAC = Water absorbsion capacity, OAC = Oil absorbsion capacity

Table 3. Granules size distribution of starch from cassava (419, um37, 30572), sweet potato (*x-igbariam*) and cocoyam (Nxs003, *edeuhie*)

Sample	Size range (Nm)	Mode (Nm)	Mean (Nm)
419	120-160	130	140
um37	200-350	210	244
30572	180-300	180	273
Pot	220-300	300	264
NXS	100-200	100	154
ede	100-200	100	154

419, um37 and 30572 are cassava starch, ede (edeuhie) and NXS (xanthosoma) are cocoyam starch, pot (x-igbariam) is white skinned sweet potato

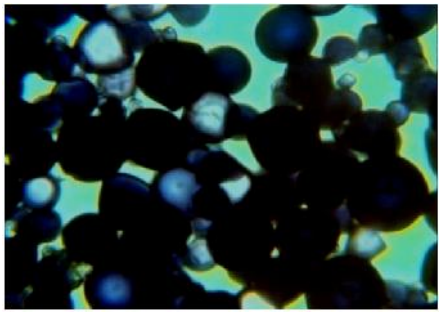

Fig. 8. Cassava 419 starch

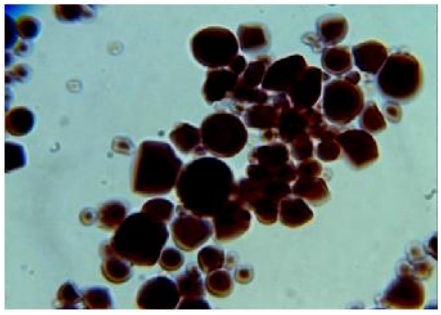

Fig. 9. Sweet-potato (*x-Igbariam*) starch

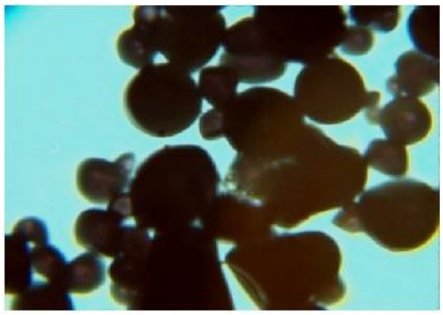

Fig. 10. Cassava 30572 starch

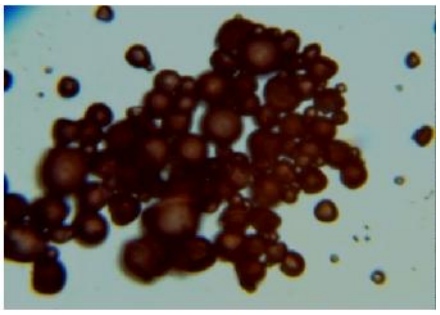

Fig. 11. Cocoyam edeuhie starch

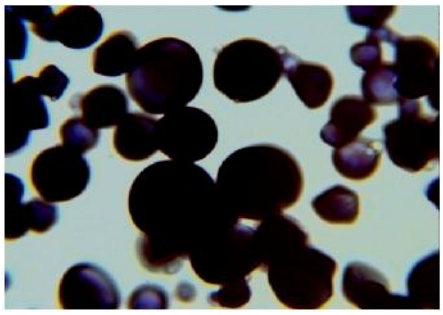

Fig. 12. Cassava um37 starch

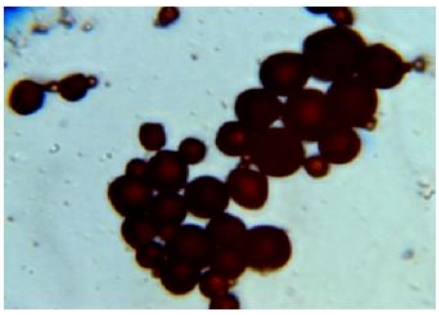

Fig. 13. Cocoyam Nxs003

Plate 2. Microscopic structure of starch from selected root crops (x400)

Key: 419, um37 and 30572 are cassava starch, cocoyam (edeuhie) and Nxs003 (xanthosoma) are cocoyam starch, pot (x-igbariam) is white skinned sweet potato

solubility and hence enhanced water absorption capacity which have positive implication for functionality of flour during processing, often creates more cohesion in most baking systems

larger granules on the other hand would be insufficiently hydrated. Optimum dough mixing would thus require fine and evenly distributed particles size flour at most 300 Nm for easy hydration [48].

3.3.1 Starch microscopy of starch from cassava (419, Um37, 30572), sweet Potato (x-igbariam) and cocoyam (Nxs003, e*deuhie*)

The microscopy results in Plate 2 showed spherical shape for all the starches visualized. Cocoyam starch particles showed a smooth, fine and regular circle shape. This result is in line with the findings of Benes [49] which reported mostly round or oval shapes with flat surface on one side containing conical pit which extends to all wall for cassava starches. Other researchers reported Round truncated, cylindrical and spherical for cassava starch granules [23,50,51,52] reported that particle size distribution of milled flours affects the rate of hydration during processing, as very fine (<180 µm) particle-sized flours have greater tendency of absorbing more water during hydration.

4. CONCLUSIONS

The starch from different tuber crops analyzed showed different physiological and micro-structural properties. Pasting temperature was highest in cocoyam starch sample (ede) while cassava starch sample 419 was the lowest in Pasting temperature. This suggests the presence of higher proportions of long amylopectin chains in cocoyam starch. Peak, trough and breakdown result was highest in sweet potato starch while peak was lowest in cocoyam starch sample. Solubility was highest in cocoyam (Ede) and lowest in cassava sample 419. The microscopic picture of starches showed spherical shape for all granules with cocoyam starch having smooth, fine and regular circle shape. Cassava starch sample 30572 was highest in granular size while 419 recorded lowest granular size.

Starch from different plants and varieties significantly differ in their functional, pasting and micro-structural properties. Different starch products require different physiological properties and when starch source is rightfully selected; different starch source shows optimum functionalities in specific product.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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