

Full Length Research Paper

## Isolation and Characterization of Starches from eight *Dioscorea alata* cultivars grown in Jamaica

Riley, C. K.<sup>1\*</sup>, Wheatley, A. O.<sup>1,2</sup> and Asemota, H. N.<sup>1,2</sup>

<sup>1</sup>Biotechnology Centre and <sup>2</sup>Department of Basic Medical Sciences (Biochemistry), University of the West Indies, Mona Campus, Kingston 7, Jamaica, W.I.

Accepted 14 July, 2006

Starches from eight *Dioscorea alata* cultivars grown in Jamaica were isolated and characterized. The starches were found to possess the open hydrated hexagonal crystalline pattern (type-B) with apparent amylose content ranging from  $20.117 \pm 0.017 \text{ gKg}^{-1}$  for Darknight yam to  $23.001 \pm 0.058 \text{ gKg}^{-1}$  for Barbados. The starch granules were found to display an asymmetric "Maltese" cross upon exposure to polarized light with projected mean granule diameters ranging from  $22.89 \mu\text{m}$  to  $28.01 \mu\text{m}$ . The starch granules were predominantly ellipsoidal in shape with only Renta yam and Barbados yam displaying triangular shaped granules. The swelling power of the starches were found to increase with temperature, with Moonshine ( $895.551 \pm 1.051\%$ ) having the highest swelling power and Renta yam ( $757.401 \pm 6.101\%$ ) the lowest at  $95^\circ\text{C}$ . Variations were also observed in the solubility, phosphorous content, crude fat content and gelatinization temperatures of the different yam starches. The properties of the different *Dioscorea alata* starches may prove useful in nutritional applications.

**Key words:** *Dioscorea alata*, yam, starch, crystallinity, amylase.

### INTRODUCTION

The yam (*Dioscorea sp.*) is a monocotyledous tuber bearing plant, belonging to the family *Dioscoreaceae* within the genus *Dioscorea* (Ayensu, 1972). The most economically important species are *D. rotundata*, *D. alata*, *D. cayenensis*, *D. bulbifera*, *D. trifida*, *D. opposita*, *D. dumentorum*, *D. japonica* and *D. hispida*. Within the genus *Dioscorea* there are five subdivisions; *Enantiophyllum* - this subdivision contains most of the economically important yam species (*D. rotundata*, *D. alata*, *D. cayenensis*, *D. opposita*, and *D. japonica*) and are characterized by the fact that the vines twines right when viewed from the ground upwards. *Lasiophyton* (*D. polygonoides* and *D. hispida*), *Oposophyton* (*D. bulbife-*

*ra*), *Combilium* (*D. esculenta*), and *Macrogynodium* (*D. trifida*) twines to the left (Osagie, 1992).

*D. alata* commonly referred to as 'winged yam', 'water yam' or 'greater yam' usually possesses tubers that are white, brown or brownish red in colour. The tubers are generally large and measure up to two meters in length. The water content of the tuber is usually high hence the name 'water yam'. Tubers from the species, *D. alata* are also known for their high nutritional content, with crude protein content of 7.4%, starch content of 75-84 %, and Vitamin C content ranging from 13.0 to 24.7 mg/100 g (Osagie, 1992). Due to the high starch content of the *D. alata* tubers they provide a good source of dietary carbohydrates in the tropic and subtropical regions (Osagie, 1992).

Over 250,000 tonnes of yams are produced annually in Jamaica, where approximately 5% is exported, resulting in an annual export earning of over US \$15 million (Whe-

\*Corresponding authors E-mail: [cliff.riley@uwimona.edu.jm](mailto:cliff.riley@uwimona.edu.jm) Tel: (876) 9771828. Fax: (876) 9773331. 21 23

atley, 2000). The remainder is consumed locally or retained for planting; however due to the poor shelf life of the tubers, a considerable amount is lost during storage (Wheatley, 2000). Post harvest exploitation of the tuber may lead to increased earnings from this crop. The high starch content of the tuber readily presents an opportunity for the exploitations. Presently, yams are not listed among the most common sources of industrial starch which is primarily provided by corn (*Zea Mayes*), potato (*Solanum* spp.), wheat (*Triticum* spp.), tapioca (*Manihott* spp.) and rice (*Oryza sativa*) (Alexander, 1996; Ostertag, 1996; Woolfe, 1992). One of the limiting factors for industrial application of non-official starches such as that from yams is the lack of adequate information on the physiochemical, fundamental and derived properties of the starches.

This study was designed to isolate and characterize starches from eight *D. alata* cultivars.

## MATERIALS AND METHODS

### Yam samples

Tubers of *D. alata* cultivars (cv) Sweet yam, White yam, Renta yam, St. Vincent Moonshine, St. Vincent Darknight, St. Vincent Purple Skin/ White flesh, Barbados and Calabash were collected from a local farm in St. Ann, Jamaica.

### Starch isolation

Starch was extracted by the method of Moorthy and Nair (1989) with modifications. The Freshly harvested yam tubers (100.0 g) were peeled and homogenized with 1 M NaCl (900.0 ml) solution using a Waring commercial blender. The mixture was filtered through triple layered cheesecloth and starch washed through using water. The granules were allowed to settle and water decanted followed by centrifugation at 3,000 x g for 10 min. Starch was allowed to air dry overnight at room temperature.

### Determination of apparent amylose content

The apparent amylose was determined by the method of Farhat et al. (1999) with modifications. Starch (500.0 mg) was defatted by standard AOAC (1990) methods using hexane. The defatted starch (100.0 mg) was dispersed in ethanol (1.0 ml) and 1 M NaCl (9.0 ml). The volume was made up to 100.0 ml with distilled water and a 5.0 ml aliquot transferred to a volumetric flask containing water (25.0 ml). 1 M Acetic acid (0.5 ml) and 1.0 ml iodine solution (0.2% iodine in 2% potassium iodide) were added and the volume made up to 50.0 ml with water and absorbance recorded at 620 nm.

### Solubility and swelling power

Starch solubility was determined by the modified method of Autio et al. (1992). Yam starch (100 mg) was suspended in 10.0 mL water followed by incubation at 30°C for 1 h. The mixture was allowed to cool to room temperature then centrifuged at 3,000 x g for 10 min. Soluble starch was determined by the modified anthrone reagent method as outlined by Loewus (1952). Starch swelling power was

determined by the modified method of Leach et al. (1959). Starch (1.0 g) was weighed each in 4 pre-weighed centrifuge tubes and volume made up to 50.0 mL with water. The tubes were sealed and incubated in water baths equilibrated at 30, 60, and 95°C for 30 min followed by centrifugation at 7,000 x g for 20 min. Swelling power was determined as the percentage change in weight of starch used.

### Determination of starch crystalline properties

Starches were stored over saturated CuSO<sub>4</sub> solution (50-55 % RH) at ambient temperature for 2 weeks. X-ray spectra were recorded with 2θ angles, 4°- 38° with step size of 0.005° at 25°C using a Bruker D5005 X-ray diffractometer. Potato, corn and pea starches were used as standards.

### Differential scanning calorimetry

Starch gelatinization was studied by the method of Purshottam et al. (1990). Starch/water mixtures (water content 80% total wet basis) were prepared directly in aluminum DSC pans and left overnight to equilibrate. Thermograms were acquired between 20 and 100°C at a heating rate 10°C/min. An empty pan served as reference.

### Microscopic studies of starch granules

Starch for scanning electron microscopic studies were sieved using a number 60 Fisher sieve, mounted and coated with gold (1 nm) using a Polaron sputter coater and analyzed using a Bruker Scanning Electron Microscope at a magnification of 3.26 x 10<sup>2</sup>. Starch granules for birefringence test were suspended in water and viewed with a Leica DMRME polarized light microscope. Projected mean granule diameter was calculated by averaging the diameter of 500 starch granules viewed with a Nikon SMZ-10 light microscope equipped with a graticulated eye piece.

The specific surface area of starch granules was calculated by using the equation for a spherical particle (Adebayo, 1998):

$$S_w = \frac{6}{\rho d_{vs}}$$

Where  $\rho$  is the density of the granule, 6 is a constant for spherical particles and  $d_{vs}$  the volume to surface ratio.

### Enzymatic degradation

Percentage digestion was determined by the method of Hassan (1992) with slight modifications. Starch (10 mg) was suspended in porcine pancreatic  $\alpha$ -amylase solution (5 mL enzyme, approximately 30 units per mg starch), buffered with 0.05 M citric acid – sodium acetate buffer pH 5.5, and 0.02% CaCl<sub>2</sub>. Samples were incubated for 24 h at 40°C and reaction stopped by addition of 1 mL of a 1 M NaOH solution, followed by centrifugation at 500 x g for 10 min. The extent of hydrolysis was calculated from the amount of reducing sugar liberated, which was determined as outlined by Nelson (1994).

### Determination of crude fat content

Fat content was determined by standard Helrich (1990) methods. Dried starch (2 g) was extracted by soxhlet for 4 h with 300 mL of a

**Table 1.** Percentage hydrolysis, Crystalline forms and Amylose content of *Dioscorea alata* starches

Yam cultivar	Crystalline form	Amylose [gKg <sup>-1</sup> ] [%]	Hydrolysis
Sweet yam	B	21.083 ± 0.051 <sup>e</sup>	15.315 ± 0.035 <sup>c</sup>
White yam	B	20.340 ± 0.029 <sup>c</sup>	15.548 ± 0.014 <sup>f</sup>
Renta yam	B	22.433 ± 0.044 <sup>d</sup>	15.368 ± 0.038 <sup>a</sup>
Moonshine	B	20.731 ± 0.131 <sup>b</sup>	15.425 ± 0.026 <sup>e</sup>
Darknight	B	20.117 ± 0.017 <sup>c</sup>	15.490 ± 0.035 <sup>d</sup>
Barbados	B	23.001 ± 0.058 <sup>f</sup>	15.305 ± 0.033 <sup>c</sup>
Purple /White	B	20.767 ± 0.159 <sup>b</sup>	15.460 ± 0.042 <sup>b</sup>
Calabash	B	22.083 ± 0.061 <sup>a</sup>	15.363 ± 0.021 <sup>a</sup>

Superscripts in the columns sharing different letters are significantly different ( $p < 0.05$ ).

hexane-chloroform (1:1 v/v) mixture. The solvent was vaporized by means of a BUCHI vacuum rotavapour R-114 and the crude fat content calculated by difference.

#### Determination of total phosphorus content

Phosphorous was determined by standard Helrich (1990) methods. Starch (2 g) was weighed and ashed at 600°C in a 150 mL ceramic beaker. The ashed samples were allowed to cool, followed by the addition of 400 mL of 1 M HCL and 5 drops of 1 M HNO<sub>3</sub>. The mixture was then heated to boiling point, then cooled, transferred to a 200 ml volumetric flask and made up to volume with water. Aliquots containing approximately 0.5-1.5 mg phosphorous were filtered and transferred to a 100 mL volumetric flask followed by the addition of 20 mL molybdovanadate reagent and volume made to 100 mL with water. The mixture was mixed thoroughly and left to stand for 10 min and transmittance at 400 nm read against a reagent blank.

#### Determination of ash content

The ash content of the yam starches was determined the standard Helrich (1990) methods. One gram (1 g) yam starch was weighed and placed in pre-weighed ceramic crucibles. The crucibles were then placed in a Thermolyne furnace at 500°C overnight (or until residue was white) and the ash content calculated by weight difference.

#### Statistical analysis

Samples were analysed in replicates of six (6) and values evaluated using the One-Way ANOVA Duncan's t-test ( $p < 0.05$ ).

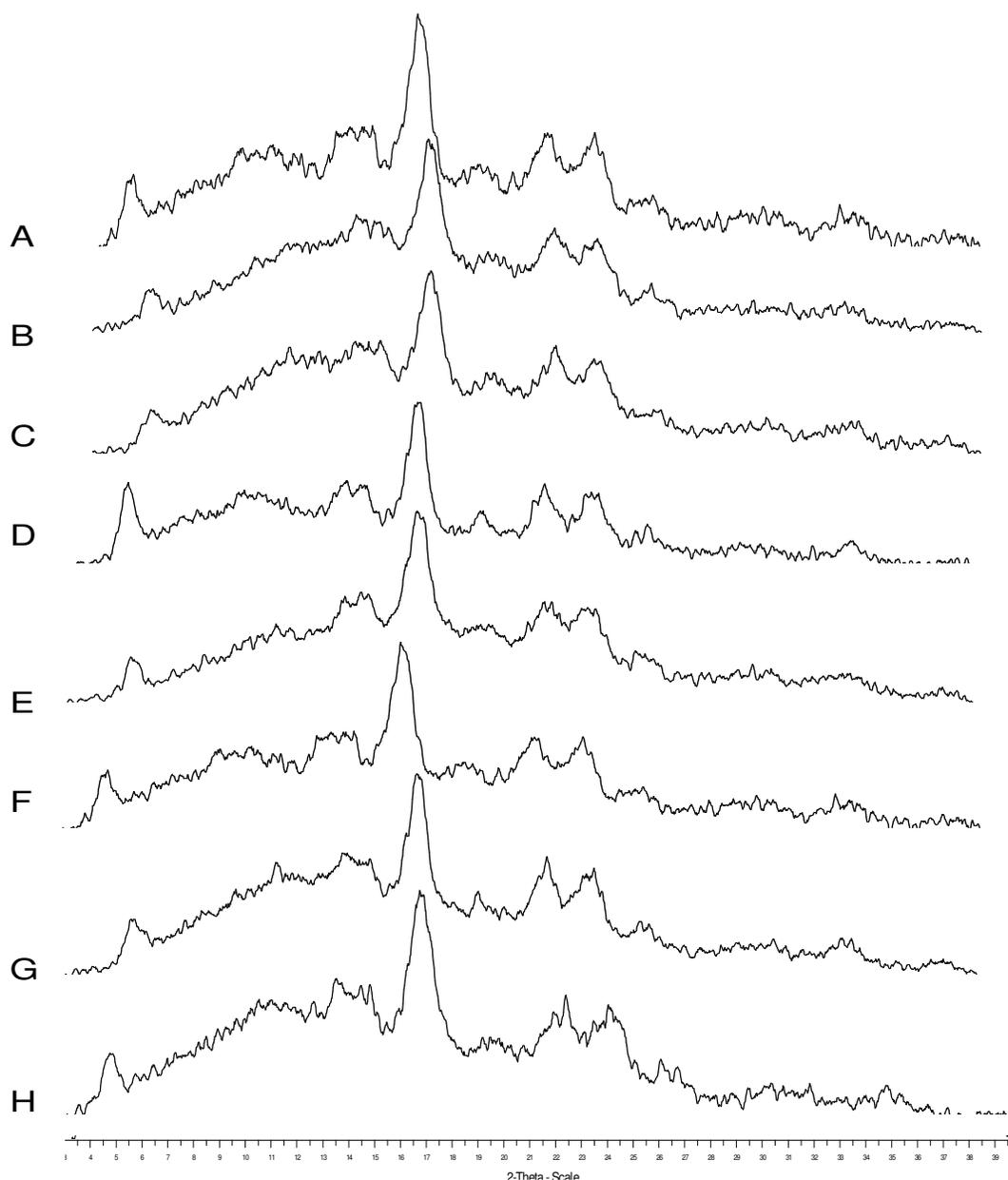
## RESULTS AND DISCUSSION

Table 1 outlines the crystallinity, amylose content and percentage hydrolysis of the different yam starches. The starches studied exhibited the open hydrated hexagonal crystalline pattern (type B) typical of tuber starches with strong diffraction peaks at approximately 5.80°θ, a single sharp peak at 17.5°θ and two identifiable peaks at 22.5°θ and 24°θ (Figure 1). The θ angles (d-spacing) were unique to each *D. alata* cultivar and were non-super

imposable. Previous studies (Duddu et al., 1997; Stahly et al., 1997) have shown that the θ angles (d-spacing) at which the peaks occurred and the intensities of the diffractions are characteristic for different materials. Thus for starch products from a given *D. alata* cultivar, the uniqueness of the x-ray diffraction patterns may serve as a qualitative test of the identity to confirm authenticity of the starch samples. In addition, the x-ray diffraction pattern could be used to indicate the presence of adulterant or the contamination of starch from another plant or yam cultivar.

It has been reported that starches with high amylose/low amylopectin contents tend to be of the type B structure, while those with low amylose/high amylopectin content are of either the type-A or the intermediate type-C form (Padmanabhan and Lonsane, 1992). The results are in correlation to these findings as all the starches studied were of the type B form and had high amylose content. Previous reports (Riley et al., 2004; El-Harith et al., 1976) have shown that type-C and type-A starches are more digestible than type-B starches. Gallent et al. (1982) reported that cooked type-A starches showed higher susceptibility to α-amylase as observed in *D. dumentorum* (97.2%) and *Manihot utilissima* (99.1%) than type B starches from *D. alata* (68.1%) and *D. cayenensis* (68.6%). The starches were found to have a low digestibility, which could have been related to their crystalline form.

The apparent amylose content also varied significantly among the starches studied ( $p < 0.05$ ). Starch from Darknight was found to have the lowest amylose content, while Barbados had the highest (Table 1). The difference in amylose content observed may be attributed to genetic variations among the varieties. In fact, it has been postulated that the amylose content of starches is affected by the expression of the amylose extender gene (Noda et al., 1992). Previous reports have shown variations in amylose content with granule diameter however no direct correlation between the two parameters was observed (Franco et al., 1988). Previous reports (Riley et al., 2004; Noda et al., 1992) has shown



**Figure 1.** X-ray diffractograms of (A) Sweet yam, (B) White yam, (C) Renta yam, (D) St. Vincent Moonshine yam, (E) St. Vincent Darknight yam, (F) Barbados yam, (G) St. Vincent Purple skin/white flesh yam and (H) Calabash yam.

that the amylose content plays a key role in the digestion of starches, as starches with low amylose contents were found to be more digestible than starches with high amylose content. Similar correlation between amylose content and *in vitro* digestibility was observed as starches with lower amylose content were more digestible than those with higher amylose content (Table 1).

The *in vitro* digestibility of different *D. alata* starches ranged from  $15.305 \pm 0.033$  to  $15.548 \pm 0.014\%$  with Darknight being the most digestible and Barbados the least. This implies that the starches may be digested and absorbed at a slow rate, thereby releasing their product

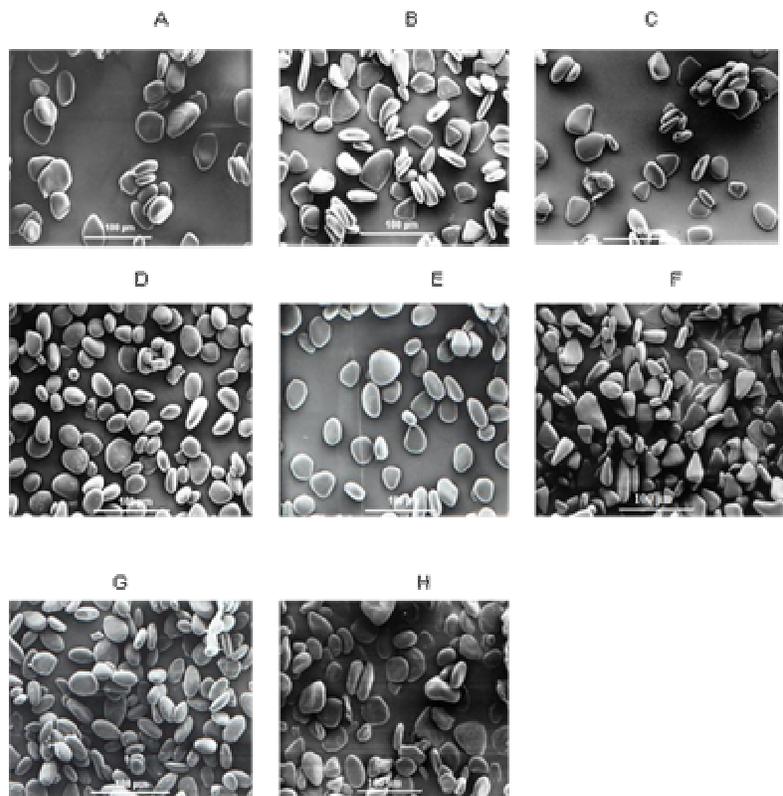
of digestion slowly as they pass through the digestive tract. Starches that are digested and absorbed at a slower rate would result in lower blood glucose responses, while those which are digested and absorbed at a faster rate would produce large increases in the blood glucose, which may necessitate greater insulin and other endocrine responses when ingested (Wolever et al., 1992; Jenkins et al., 1982). The low digestibility of the starches could be of significance to diabetics and other health conscious individuals.

The particle size of the White yam, Moonshine, Darknight, Calabash and Purple/ White yam starches

**Table 2.** Granule shape, projected mean diameter and specific surface area of *Dioscorea alata* starches

Yam cultivar	Granule Shape	Mean diameter [ $\mu\text{m}$ ]	Specific Surface area [ $\text{m}^2\text{Kg}^{-1}$ ]
Sweet yam	Ellipsoid	25.16 <sup>e</sup>	151.091 <sup>d</sup>
White yam	Polyhedral	27.33 <sup>a</sup>	140.850 <sup>a</sup>
Renta yam	Triangular, Ellipsoid	28.01 <sup>d</sup>	135.52 <sup>d</sup>
Moonshine	Ellipsoid	23.74 <sup>c</sup>	175.54 <sup>c</sup>
Darknight	Ellipsoid	22.89 <sup>b</sup>	176.33 <sup>c</sup>
Barbados	Triangular, Ellipsoid	27.65 <sup>a</sup>	142.25 <sup>a</sup>
Purple /white	Ellipsoid, Rod like	27.70 <sup>a</sup>	136.61 <sup>b</sup>
Calabash	Ellipsoid	27.80 <sup>a</sup>	143.90 <sup>a</sup>

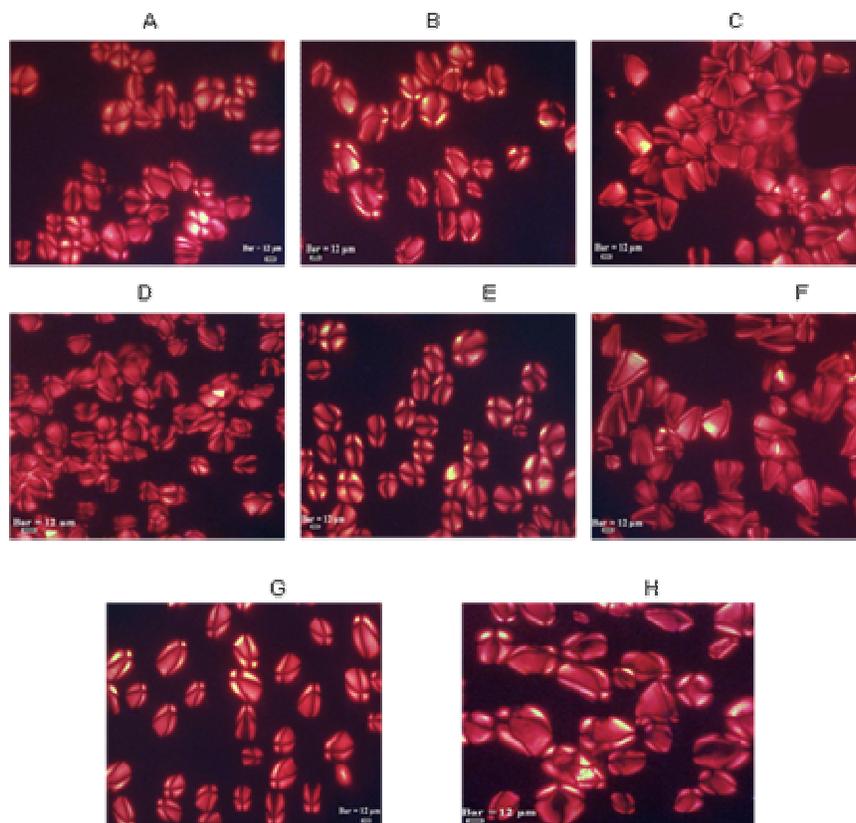
Superscripts in the columns sharing different letters are significantly different ( $p < 0.05$ ).



**Figure 2.** Scanning Electron micrographs of (A) Sweet yam, (B) White yam, (C) Renta yam, (D) St. Vincent Moonshine yam, (E) St. Vincent Darknight yam, (F) Barbados yam, (G) St. Vincent Purple skin/white flesh yam and (H) Calabash yam.

displayed a single symmetrical distribution centered at approximately 27.33, 23.74, 22.89, 27.80 and 27.70  $\mu\text{m}$ , respectively, whereas Renta yam, Barbados and Sweet yam exhibited a non-symmetrical and wider particle size distribution centered at 28.01, 27.5 and 25.16  $\mu\text{m}$ , respectively (Table 2, Figure 2). The starch granules were predominantly ellipsoidal; however Renta yam and Barbados had triangular shaped granules. The specific surface area was found to be dependent of the granule diameter, where Sweet yam was found to possess the

highest specific area and Renta yam the lowest. Particle size and specific surface area were observed to play key roles in the digestibility of the yams starches, as it was found that smaller starch granules were more digestible than the larger granules. The particle size and specific surface area also has significant implications on processing of pharmaceutical formulations in which they are present. Finer particles tend to have a greater number of particles per unit weight which is indicative of a higher potential for achieving homogeneity when mixing



**Figure 3.** Polarised light micrographs of (A) Sweet yam, (B) White yam, (C) Renta yam, (D) St. Vincent Moonshine yam, (E) St. Vincent Darknight yam, (F) Barbados yam, (G) St. Vincent Purple skin/white flesh yam and (H) Calabash yam.

the substance with active pharmaceutical ingredient and other powder ingredients. The higher specific surface area of the finer particles may have improved their adsorption capacity, which could be utilized as absorbents in formulations where the Active pharmaceutical ingredient (API) is in a liquid state, such as those containing aromatic flavoring oils (Adebayo and Itiola, 1998). Starch from Moonshine and Darknight tubers would be expected to have a higher potential for achieving homogeneity in its compacts and have a better absorptive capacity as opposed to the other starches studied as a result of the small particle diameter and high specific surface area.

All the starches studied displayed birefringence upon exposure to polarized light, thus indicating some degree of crystallinity or granular order within the starch granular matrix (Figure 3). Birefringence is indicative of the spot (hilum) where starch deposition originated during development in the leucocyte. Starch granules without a hilum generally do not show birefringence. Those which are unevenly distributed indicate that deposition progressed at a faster rate along some direction than others, which is in part affected by the pressure/obstruction in that direction (Adebayo, 2001). Theoretically starch in aerial organs are expected to experience less

pressure and be uniform, hence symmetrical maltese cross while those in underground organs/tissues are expected to be more condensed, hence asymmetric with fewer maltese crosses (Adebayo, 2001). The results from this study were in correlation with this theory as all the starches displayed a non-symmetrical maltese cross typical of underground borne tubers.

The gelatinization temperature of the different *D. alata* starches displayed a single endothermic peak which varied from 74.321 to 76.931 °C (Table 3, Figure 4) with White yam having the lowest and Renta yam the highest. The enthalpy of gelatinization varied significantly among the different yam starches with Sweet yam starch having the lowest and Moonshine the highest (Table 3).

The solubility of the different starches varied significantly ( $p < 0.05$ ) with Renta yam having the lowest and Moonshine the highest (Table 4). The solubility of starches is believed to be affected by factors such as inter-associative forces, swelling power, presence of surfactants and other associative compounds (Moorthy, 2002; Sibanda et al., 2000; Soni et al., 1985). The solubility values observed would appear to be related to the starch granule size and amylose content, where it was observed that solubility increased with smaller granule size and lower amylose content. The swelling

**Table 3** Gelatinization temperature and Enthalpy of gelatinization for *Dioscorea alata* starches

Yam cultivar	T <sub>o</sub> (°C)	T <sub>p</sub> (°C)	T <sub>f</sub> (°C)	Enthalpy change (J/g)
Sweet yam	73.011	75.401	79.011	4.800
White yam	72.090	74.321	77.050	11.311
Renta yam	72.931	76.931	79.120	6.720
Moonshine	73.201	75.711	80.230	12.750
Darknight	73.361	75.691	79.501	6.110
Barbados	72.851	76.900	79.321	7.100
Purple /white	74.181	76.490	79.511	8.450
Calabash	71.362	74.430	78.871	11.510

T<sub>o</sub> - onset temperatureT<sub>p</sub> - peak temperatureT<sub>f</sub> - final temperature**Table 4.** Solubility and swelling power of *Dioscorea alata* starch granules

Yam cultivar	Solubility (gKg <sup>-1</sup> )	Swelling Power (%)		
		30 °C	60 °C	95 °C
Sweet yam	0.433 ± 0.002 <sup>g</sup>	141.510 ± 0.712 <sup>b</sup>	157.051 ± 0.651 <sup>a</sup>	840.051 ± 2.650 <sup>h</sup>
White yam	0.419 ± 0.006 <sup>a</sup>	106.650 ± 0.100 <sup>a</sup>	146.601 ± 0.201 <sup>d</sup>	851.851 ± 6.951 <sup>g</sup>
Renta yam	0.408 ± 0.001 <sup>f</sup>	130.301 ± 0.861 <sup>d</sup>	144.901 ± 1.001 <sup>c,d</sup>	757.401 ± 6.101 <sup>f</sup>
Moonshine	0.463 ± 0.012 <sup>e</sup>	109.710 ± 0.601 <sup>c</sup>	144.291 ± 5.221 <sup>c,d</sup>	895.551 ± 1.051 <sup>e</sup>
Darknight	0.456 ± 0.002 <sup>d</sup>	111.810 ± 1.021 <sup>c</sup>	142.821 ± 1.861 <sup>c</sup>	885.231 ± 5.261 <sup>d</sup>
Barbados	0.412 ± 0.003 <sup>c</sup>	105.610 ± 0.621 <sup>a</sup>	140.251 ± 0.991 <sup>c</sup>	775.001 ± 3.251 <sup>c</sup>
Purple /white	0.449 ± 0.002 <sup>b</sup>	141.010 ± 0.200 <sup>b</sup>	189.710 ± 1.801 <sup>b</sup>	787.201 ± 8.301 <sup>s</sup>
Calabash	0.417 ± 0.002 <sup>a</sup>	104.901 ± 0.611 <sup>a</sup>	158.500 ± 7.301 <sup>a</sup>	826.101 ± 1.501 <sup>a</sup>

Superscripts in the columns sharing different letters are significantly different (p&lt;0.05).

power of the starches also varied significantly (p<0.05) with temperature as the swelling power was found to increase with increasing temperature (Table 4). The low swelling power displayed by some of the yam starches may be a result of the extensive and strongly bonded micellular structure; as such starches are relatively resistant to swelling (Lorenz, 1990). A greater swelling in starches with low amylose content should occur, which indicates that amylose reinforces the internal network within the granules thus restricting swelling. This was observed in Sweet yam, Moonshine, Darknight and Purple/White yam starches which had low amylose content and high swelling power. Purshottam et al. (1990) reported on the involvement of starch lipids in swelling, where it was shown that high fat content impedes swelling, however no direct correlation was observed among the *D. alata* starches which could possibly be associated with the low starch lipid content. The swelling power of starches is of great significance in tablet and capsule formulations, as it is believed that disintegrants work through a swelling and wicking action (Adebayo and Itiola, 1998). As a result starches with higher swelling power would be expected to release the active pharmaceutical ingredient from its compacts at a faster

rate. This therefore implies that tablet and capsule formulated with Purple skin/white flesh and Sweet yam starches as disintegrants would release the drug at a fastest rate while those formulated with White yam and Barbados starch would be slowest.

Table 5 shows the phosphorous and ash content of the different starches, where White yam had the highest content and Darknight the lowest. Phosphorous is the most dominant mineral in starches, and is found in one form or another (Mcintire et al., 1990). The nature of phosphorous is believed to affect the starch performance, however phosphorous in tuber starches, such as potato is dominant in the form of phosphomonoesters which occurs on the starch molecule as negatively charged groups (Morrison et al., 1995). The ionic repulsion generated by these groups weakens the association forces between the molecules thereby increasing the water binding capacity, swelling power and the paste clarity. However, no such correlation was observed between the phosphorous and swelling power of the different starches. The presence of phosphomonoester groups makes the starches more anionic and thus more feasible or favoured in food applications which require high gel strength (Ellis et al., 1998).

**Table 5.** Phosphorous, fat and ash content of *Dioscorea alata* starches

Yam cultivar	Phosphorous content [mg/g starch]	Ash content (%)	Fat content (%)
Sweet yam	0.233 ± 0.005 <sup>f</sup>	0.365 ± 0.038 <sup>h</sup>	0.685 ± 0.059 <sup>f</sup>
White yam	0.276 ± 0.002 <sup>e</sup>	0.231 ± 0.011 <sup>g</sup>	0.501 ± 0.026 <sup>a</sup>
Renta yam	0.252 ± 0.006 <sup>c</sup>	0.378 ± 0.004 <sup>f</sup>	0.567 ± 0.032 <sup>e</sup>
Moonshine	0.150 ± 0.005 <sup>d</sup>	0.238 ± 0.013 <sup>e</sup>	0.731 ± 0.031 <sup>d</sup>
Darknight	0.148 ± 0.003 <sup>b</sup>	0.241 ± 0.015 <sup>d</sup>	0.730 ± 0.029 <sup>d</sup>
Barbados	0.250 ± 0.005 <sup>c</sup>	0.381 ± 0.004 <sup>c</sup>	0.570 ± 0.009 <sup>c</sup>
Purple /white	0.144 ± 0.006 <sup>b</sup>	0.190 ± 0.001 <sup>b</sup>	0.521 ± 0.023 <sup>b</sup>
Calabash	0.281 ± 0.010 <sup>a</sup>	0.511 ± 0.001 <sup>a</sup>	0.505 ± 0.054 <sup>a</sup>

Superscripts in the columns sharing different letters are significantly different ( $p < 0.05$ ).

## Conclusions

The study revealed significant differences in the physico-chemical properties of *D. alata* starches. All the starches were found to possess the open hydrated hexagonal crystalline pattern (type B), where the diffractograms were non-superimposable, therefore unique to each yam cultivar. This could possibly be used as a diagnostic tool for cultivar identification. The variations in the physico-chemical properties of the different yam starches studied could be of significance in the formulation of diets for diabetics and other health conscious individuals and also for use as binders or disintegrants in tablet and granule formulations.

## ACKNOWLEDGEMENTS

The authors are grateful to the School of Graduate Studies and Research and the Biotechnology Centre, University of the West Indies (Mona Campus) for funding this research the Electron Microscopy Unit and the X-Ray lab at the University of the West Indies (Mona Campus) for technical assistance.

## REFERENCES

- Adebayo AS (2001). A study of breadfruit and cocoyam starches as excipients in paracetamol tablet formulations. PhD dissertation, University of Ibadan, Ibadan, Nigeria.
- Adebayo AS, Itiola OA (1998). Evaluation of breadfruit and cocoyam starches as exodisintegrants in a paracetamol tablet formulation. *Pharm. Pharmacol. Commun.* 4, 385-389.
- Alexander RJ (1996). Starch in plastics. *Cereal Foods World* 41: 426-427.
- Autio K, Suortti T, Hamunen A, Poutanen K (1992). Microstructural and physicochemical properties of oxidised potato starch for paper coating. *Starch/Stärke* 44: 393-398.
- Ayensu ES, Coursey DG (1972). Guinea yams. The botany, ethnobotany, use and possible future of yams in West Africa. *Econ. Bot.* 26: 301-318.
- Duddu SP, Khin-Khin A, Grant DJW, Suryanarayanan R (1997). A novel x-ray powder diffraction method for studying the reaction between pseudoephedrine enantiomers. *J. Pharm. Sci.* 86: 535-537.
- El-Harith A, John WT, Dickerson JW, Walker R (1976). Nutritive value of various Starches for Albino Rat. *J. Sci. Food Agric.* 27: 521-526.
- Ellis RP, Cochrane PM, Dale FM, Duffus CM, Lynn A, Morrison IM, Prentice DR, Swanston SJ, Tiller SA (1998). Starch Production and Industrial Use. *J. Sci. Food Agric.* 77: 289-311.
- Farhat IA, Oguntona T, Roger NJ (1999). Characterisation of starches from West African Yam. *J. Sci. Food Agric.* 79: 2105-2112.
- Franco MLC, Ciacco CF, Tavares DQ (1988). Studies on the susceptibility of granular cassava and corn starches to enzymatic attack, Part 2. Studies on the granular structure of starch. *Starch/Stärke* 40: 29-32.
- Gallent DJ, Bouchet B, Buleon AY, Pirez S (1982). Physical characteristics of starch granules and susceptibility to enzymatic degradation. *Eur. J. of Clin. Nutr.* 46: 3-16.
- Hassan HS, West L (1992). Studies on starch granules digestion by  $\alpha$ -amylase. *Starch/Stärke* 44: 61-63.
- Helrich K (1990). Official Methods of Analysis 15<sup>th</sup> Edition. Association of Official Analytical Chemist Inc., Virginia, p.70.
- Jenkins DJ, Taylor RH, Wolever TMS (1982). Relationship between the rate of digestion of foods and post-prandial glycaemia. *Diabet.* 23: 477.
- Leach HW, McCowan LD, Schoch TJ (1959). Swelling and solubility patterns of various starches. *Cereal Chem.* 36: 534-544.
- Loewus FA (1952). Improvement in anthrone method for determination of carbohydrates. *Anal. Chem.* 24: 51-59.
- Lorenz K (1990). Quinoa (*Chenopodium quinoa*) starch: Physico-chemical properties and functional characteristics. *Starch/Stärke* 42: 81-86.
- McIntire DD, Ho C, Vogel HJ (1990). One-dimensional nuclear magnetic resonance studies of starch and starch products. *Starch/Stärke* 42: 260-267.
- Moorthy SN (2002). Physicochemical and functional properties of tropical tuber starches: A review. *Starch/Stärke* 54: 559-592.
- Moorthy SN, Nair SG (1989). Studies on *Dioscorea rotundata* starch properties. *Starch/Stärke* 41: 81-83.
- Morrison WR (1995). Starch lipids and how they relate to starch granule structure and functionality. *Cereal Foods World* 40: 437-446.
- Nelson NJ (1994). A photometric adaptation of the Somogyi method for the determination of glucose. *J. Biol. Chem.* 153: 375-380.
- Noda T, Takahata Y, Nagata T (1992). Developmental changes in the properties of sweet potato starches. *Starch/Stärke* 44: 405-409.
- Osagie AU (1992). The yam tuber in storage. Ambik, Benin City, Nigeria, pp. 33-84.
- Ostertag C (1996). World production and marketing of starch. In: Cassava flour and starch: progress in research and development. Cali. Columbia, pp. 105-120.
- Padmanabhan S, Lonsane BK (1992). Comparative physico-chemical and functional properties of cassava starches obtained by conventional and enzyme-integrated conventional techniques. *Starch/Stärke* 44: 328-331.
- Purshottam LS, Harshwardhan S, Harish CS, Mahendrasinh MG (1990). Physiological properties of *Canna edulis* starch-Comparison with maize starch. *Starch/Stärke* 42: 460-464.
- Riley CK, Wheatley AO, Hassan I, Ahmad MH, Morrison E St. Y, Asemota HN (2004). *In vitro* digestibility of raw starches extracted

- from five yam (*Dioscorea spp.*) species grown in Jamaica. Starch/Stärke 56: 9-73.
- Sibanda S, Sibanda S, Sychawska B (2000). A comparative study of wild yam starch from *Dioscorea schimperiana*. J. Appl. Sci. South Africa 6: 79-86.
- Soni PL, Sharma HW, Dobhal NP, Bisen SS, Srivastava HC, Gharia MM (1985). The starches of *Dioscorea ballophylla* and *Amorphophalus*. Comparison with tapioca starch. Starch/Stärke 37: 6-9.
- Stahly GP, McKenzie AT, Andres CA, Byrn SR, Johnson P (1997). Determination of the optical purity of Ibuprofen using x-ray diffraction. J. Pharm. Sci. 86: 970-971.
- Wheatley AO (2000). Biochemical and physiological factors affecting the lab to field transfer of *in vitro* derived yam (*Dioscorea spp.*) plantlets. PhD. dissertation, University of the West Indies, Mona, Jamaica.
- Wolever TMS, Jenkins DJA, Vuksan V, Jenkins AL, Buckley GC, Wong GS, Josse RG (1992). Beneficial effect of a low-glycaemic index diet in type 2 diabetes. Diabet Med. 9: 451-458.
- Woolfe JA (1992). Sweet potato an untapped food resource. Cambridge University press. UK, p.643.