RESEARCH ARTICLE

Effect of harvesting periods on the morphology and physico-chemical properties of trifoliate yam starches

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Trifoliate yam starches from white and yellow cultivars were isolated and characterized by SEM, granule size analysis, pasting properties and swelling characteristics at different harvesting periods were studied. The starch yield ranged from 5.09 to 12.07%. White trifoliate yam had the highest starch yield at 9 months and this was significantly different ($p<0.05$) from others. The scanning electron micrograph revealed the presence of smooth surface granules with polygonal granule size ranging from 2.58 to 3.58 μm in diameter. Amylose and starch contents ranged from 14.65 to 17.44% and 40.73 to 63.34%, respectively. Peak viscosity ranged from 199.77 to 373.71 RVU, holding strength from 77.68 to 167.84 RVU, breakdown 96.79 to 217.14 RVU, final viscosity 149.84 to 267.58 RVU, setback 50.34 to 112.27 RVU. White trifoliate yam starch at 7 months had the highest peak viscosity and breakdown but it exhibits high value in holding strength at 8 months. White trifoliate yam starch harvested at 10 months had the highest swelling power at 60 and 80°C while at 90°C, the highest value was recorded for starch at 11 months. The yellow starch at 10 months had higher swelling power at 90°C. Harvesting of trifoliate yam at different periods produced starches that can be used for different purposes.

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1 Introduction

Starch is the predominant food reserve substance in plants and provides 70–80% of the calories consumed by humans worldwide [1]. Starch occurs in the form of granules which have usually an irregular rounded shape, ranging in size from 2 to 100 μm. Both the shapes and sizes of the granules are characteristic of the species of plant and can be used to identify the origin of a starch or flour [2]. Starch granules are composed of a mixture of two polymers: an essentially linear polysaccharide called amylose, and a highly branched polysaccharide called amylopectin [1]. Starch is an important ingredient in various food systems as thickening, gelling and binding agents. It imparts texture to a great diversity of foodstuffs such as soups, potages, sauces and processed foods [3, 4]. Yams, the edible tubers of various species of the genus *Dioscorea*, are important staple foods and a potential source of ingredients for fabricated foods in many tropical countries because of their high starch content [5]. Yams could also constitute alternative sources of commercial starch and detailed knowledge of their structure and functional properties is essential to extend their potential for use in food and non-food applications [6]. The starches from various root and tubers crops had been studied [6–11] but there is limited information on the effect of harvesting periods on the properties of trifoliate yam starch. After reaching maturity stage, trifoliate yam tubers are kept in the ground and little quantities are harvested for immediate consumption due to hardening process which occurs in the tubers few hours after harvesting. Due to this, the harvesting periods are prolonged until the next raining season. Thorough study on the trifoliate yam starches harvested at different periods after maturity is essential to know the changes in the properties of the starches. Therefore, this study evaluates the effect of harvesting periods on the morphology and physico-chemical properties of trifoliate yam starches.

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2 Materials and methods

2.1 Materials

The trifoliate yam setts of two cultivars (white and yellow) were planted on a farm in Osogbo, Osun State (Nigeria). Planting was done on 20th March 2011 and sprouting of some of the yam setts occurred on 26th of April 2011. These trifoliate yam setts were marked and used for the study. The trifoliate yam tubers were harvested at a month interval for five months (November 26th 2011–March 26th 2012).

2.2 Methods

2.2.1 Starch extraction

The method adopted by Akinwande et al. [12] was used for the extraction of starch. The tuber pieces were cut into small cubes and homogenized in a blender for about 2 min at the minimum speed setting available. The blending was done intermittently to prevent the starch from heating up. The resultant slurry was packed into a muslin cloth and lowered into distilled water inside a bucket. The cloth was held at the ends and the contents were continuously squeezed to expel the starch into the water. The starch was allowed to settle and the supernatant was decanted off. Further rinsing of the starch with water, settling of the starch granules and decantation of the supernatant removed the soluble impurities. This process was repeated till the supernatant was as clear as the distilled water. The wet starch was spread out on trays and allowed to dry at 45°C in a cabinet drier till the following day and was milled to a fine powder by a micro mill.

2.2.2 Determination of starch yield

Starch was estimated by the method of Balagopalan et al. [13]. A measured weight (500 g) of the sample was homogenized in a laboratory blender for 3 min. The homogenate was transferred to a plastic bowl through a 250-millimicron sieve using excess distilled water to wash off the sides of the blender. The residue collected in the sieve was discarded while the starch in the filtrate was allowed to stand undisturbed for 3 h. The water above the starch sediment was carefully decanted while the starch itself was scrapped into previously weighed drying pans. The starch in the pan was then dried in the oven at 65–70°C until the water was driven off. After cooling in a desiccator, the pan (and starch content) was reweighed and the weight of starch determined by difference. It was expressed as percentage of the weight of the sample analysed. It was calculated as shown below:

$$\text{Starch yield} = W1 - W2/\text{Weight of sample} \times 100$$

$$W1 = \text{Weight of pan} + \text{dried starch}$$

$$W2 = \text{Weight of empty drying pan}$$

2.2.3 Morphological structure of starch using scanning electron microscope (SEM)

Dry starch sample (20 mg) was suspended into 25 mL of distilled water in a clean, sealable 50 mL container. It was shaken for 1 min and was put in an ultrasonic bath for 1 min (Aqua sonic brand ultrasonic cleaner, Model 50T, approximately 200 W output). The starch suspension was gently agitated and 50 μL were transferred to a square glass slide. The drop was thoroughly spread on the slide until it wets the entire square and was air dried. It was carbon-coated with evaporated carbon (Emitech Model K450 carbon evaporator) and gold coated with a gold sputter-coater for 30 s (Cressington Model 108 sputter coater fitted with a gold target). The images of samples were received by the SEM (JSM-840 Scanning Electron Microscope) at 8 kV accelerating voltage and magnified 1000 and 3000 times. The electron beam current was 1E-11amps with objective aperture of 70 μm and working distance of 25 mm.

2.2.4 Grain diameter measurement

Starch grain diameters were measured with digital image processing system (DIPS) (the digital imaging software program that accompanies the SEM). SEM images are internally calibrated with the system.

2.2.5 Amylose content

Starch sample (0.1 g) was weighed into 50 mL test tube and 1 mL of 95% ethanol was added to wet and disperse the sample [14]. Subsequently, 9.0 mL of 1 N NaOH was added and the test tube was heated in a boiling water bath for 10 min to solubilize the sample. From the solution, 1 mL was pipetted and made up to 10 mL with distilled water in another test tube while 0.5 mL aliquot was drawn into another test tube from this solution and assayed by the addition of 0.1 mL 1 N acetic acid and 0.2 mL of iodine solution to allow colour development The solution was diluted to 10 mL with distilled water, vortexed and left for 20 min for colour development after which the absorbance was read on a spectrophotometer (Milton Roy Spectronic 601) at 620 nm.

A calibration curve was obtained from different solutions of amylose concentrations using corn amylose. Concentration factor (F) was obtained from the curve and amylose content was calculated as follows:

$$\%\,\text{Amylose} = F \times A \times \text{DF}$$

$$\%\,\text{Amylopectin} = 100 - \%\,\text{amylose}$$

where F is the concentration factor from standard, A the absorbance of solution and DF is the dilution factor.

2.2.6 Starch contents

Dry trifoliate yam flour sample (25 mg) was weighed into a centrifuge tube and wetted with 1 mL of 95% v/v hot ethanol at room temperature [15]. The sugar was extracted and the residue was hydrolysed with 7.5 mL perchloric acid into monosaccharide sugars for 1 h. It was diluted with 17.5 mL-distilled water and filtered through Whatman no. 2 filter paper. The sugar filtrate was used for starch analysis. An aliquot of each of the sugar solutions (0.1 mL) was made up to 1 mL with distilled water and colour was developed for the standard curve preparation. The standard curve was prepared by pipeting 0, 0.1, 0.2, 0.3 and 0.4 mL of glucose solution into test tubes and was made up to 1.0 mL with distilled water. These corresponded to 0, 10, 20, 30 and 40 μm glucose/mL, respectively. Into these solutions, 0.5 mL of phenol was added with subsequent addition of 2.5 mL concentrated sulphuric acid. The solutions were mixed thoroughly and then allowed to cool before being read at 490 nm on the spectrophotometer (Milton Roy Spectronic 601). A calibration standard curve of absorbance against glucose concentration was plotted from which the percentage sugar and starch in the sample were calculated.

$$\%\,\text{Starch} = \frac{(A - I) \times \text{DF} \times V \times 0.9}{B \times W \times 106} \times 100$$

where A is the absorbance of sample, I the intercept of standard curve, DF the dilution factor based on the aliquot of sample extract taken for assay, V the total extract volume, B the slope of the standard curve and W is the sample weight.

2.2.7 Swelling power determination

This was determined as described by Appiah et al. [16]. One gram of the starch sample was mixed with 10 mL distilled water in a centrifuge tube and heated in a hot water bath at 60, 70, 80 and 90°C for 30 min while continuously shaking the tube. After heating, the suspension was centrifuged at 1000 g for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling power was calculated as:

Swelling power = weight of the paste/weight of dry starch.

2.2.8 Pasting properties determination

The pasting profile of the starch sample was studied using a Rapid Visco-Analyzer (RVA) (Newport Scientific Pty. Ltd) with the aid of a thermocline for windows version 1.1 software (1998). The RVA was connected to a PC where the pasting properties and curve were recorded directly. Flour suspension was prepared by addition of the equivalent weight of 3.0 g flour to distilled water to make a total of 28.0 g suspension in the RVA sample canister. The flour suspension temperature was held at 50°C for 1 min and later heated to 95°C for 3 min. It was held at 95°C for 3 min before the sample was subsequently cool to 50°C over a 4 min period. This was followed by a period of 1 min where the temperature was kept at constant temperature of 50°C. The equivalent sample weight (S) and volume of water (W) were calculated using formulae below:

$$\text{Sample weight}(S) = \frac{A \times 100}{100 - M}$$

$$\text{Volume of water } (W) = 28 - S$$

where $A = 3$ g, S is the calculated sample weight for RVA, M the moisture content of the sample and W is the volume of water.

Parameters measured (RVA units) were:

Peak viscosity: highest viscosity during 95°C heating stage
Holding strength: lowest viscosity at the end of 95°C heating stage
Breakdown: change in viscosity from peak to holding strength
Cold paste (final) viscosity: highest viscosity at the end of 50°C cooling stage.
Setback: change in viscosity from holding strength to final viscosity.

2.3 Statistical analysis

All analyses were carried out in three triplicates. The mean and SD of the data obtained were calculated. The data were evaluated for significant differences in their means with Analysis of Variance (ANOVA) ($p \leq 0.05$). Differences between the means were separated using turkey test as packaged by SPSS software (version 17.0).

3 Results and discussion

3.1 Starch yield

The trifoliate yam tubers used are the true domesticated type (Table 1). The starch yield for the white and yellow trifoliate yam tubers are presented in Table 2. The starch yield of trifoliate yam ranged from 5.09 to 12.07%. Among the white cultivar, the starch extracted at 9 months had higher value than the other starches. The value was significantly different ($p \leq 0.05$) from other starches at different harvesting periods. There was increase in the starch yield till 9 months and then, the starch yield declined down till 11 months. Likewise, the yellow cultivar followed the same trend with the white cultivar. The starch yields of white trifoliate yam tubers were higher than that of yellow cultivar. The starch yields of trifoliate yam tubers were lower than that of potato (39.62–57.26%), *D. alata* (17.0%), *D. rotundata* (18.8%) and

Table 1. Characterization of white and yellow trifoliate yam tubers

Parameters	White cultivar (true domesticated type)	Yellow cultivar (true domesticated type)
Tuber shape	Irregular (6)	Irregular (6)
Root on tuber surface	Many (5)	Few (3)
Place of root on tuber surface	Entire (4)	Upper region (3)
Tuber attachment pattern	Highly attached (5)	Highly attached (5)
Relationship of tuber	Fused at neck region (3)	Fused at neck region (3)
Crack on tuber	Highly cracked (5)	Slightly cracked (3)

D. esculenta (17.7%) [17, 18]. The lower starch yield at 7 and 8 months may be due to the high moisture contents in the tubers which caused reduction in the dry matter of the tuber. But the reduction in the starch yield from 10 to 11 months may probably be due to sprouting of tuber.

3.2 Starch morphology and granules size

The structures of trifoliate yam at different periods are shown in Fig. 1. The shapes of the starches when viewed with SEM were polygonal in shape. The photographic structure revealed the presence of smooth surface granules with no evidence of fissures. There were no observable differences in the shapes of the granules from starches harvested at different periods for both trifoliate yam cultivars. Trifoliate yam starches had similar shapes with that observed by Sahore and Amani [19] and Okunlola and Odeku [20]. The smallest granule was observed in yellow trifoliate yam starch harvested at 11 months (2.15 μm) (Table 2). Larger granule size was recorded for white trifoliate starch harvested at 10 months (3.58 μm) but was not significantly different (p>0.05) from starches at other periods except in yellow cultivar harvested at 11 months. Trifoliate granule size diameter reported by Sahore and Amani [19] and Okunlola and Odeku [20] were 3 and 3.45 μm, respectively. The granules diameter obtained were within the reported values for trifoliate yam starches [21–23]. The granule size is reported to affect some functional properties such as swelling, solubility and digestibility [18]. The smaller granule sizes improve the digestibility because smaller granules have a greater surface area and are more rapidly digested by amylases [24]. Starch granule size may affect its physicochemical properties, such as gelatinization and pasting, swelling power, paste clarity, enzyme susceptibility, crystallinity, solubility, water-binding capacity [25–27]. The use of smaller granule size starch may be applicable in products requiring products with smooth textured starch gel [28].

3.3 Amylose content

Amylose contents were high at 7 months for both cultivars and later decreased at 8 months. There was sharp rise in the amylose contents at 9 months for both cultivars but these values later decreased with prolonged harvesting time. No significant differences (p>0.05) exit between white trifoliate yam starch at 9 months and yellow trifoliate yam starches at 9 and 10 months. This finding was contrary to the observations of Liu et al. [29] who reported highest amylose values at the shortest harvesting time for potato varieties during growth. Huang et al. [30] also observed increase in amylose contents of some *D. alata* varieties during growth. The amylose contents reported for *D. alata* ranged from 23.5 to 39.0%, potato

Table 2. Starch yield, granule size, amylose and starch contents of trifoliate yam starch[a),b)]

Cultivar	Harvesting period	Starch yield (%)	Average granule size (μm)	Amylose (%)	Starch (% db)
WC	7	7.14 ± 0.35d	3.05 ± 0.28ab	15.35 ± 0.06abc	60.23 ± 0.02e
	8	7.88 ± 0.63e	2.58 ± 0.18ab	14.65 ± 0.30a	61.54 ± 0.08f
	9	12.07 ± 0.56i	3.03 ± 0.11ab	17.44 ± 0.25f	63.34 ± 0.47g
	10	11.55 ± 0.85h	3.58 ± 0.11b	16.15 ± 0.22cd	62.27 ± 0.09f
	11	8.06 ± 0.80f	2.73 ± 0.04ab	15.04 ± 0.25ab	55.38 ± 0.35d
YC	7	5.09 ± 0.38a	3.48 ± 0.60b	16.22 ± 0.55cde	53.58 ± 0.38c
	8	6.04 ± 0.16c	2.75 ± 0.14ab	15.69 ± 0.40bc	54.39 ± 0.19cd
	9	8.52 ± 0.28g	2.90 ± 0.07ab	17.17 ± 0.13ef	54.61 ± 0.09cd
	10	7.19 ± 0.24d	2.68 ± 0.25ab	16.81 ± 0.05def	49.17 ± 0.07b
	11	5.89 ± 0.12b	2.15 ± 0.30a	15.43 ± 0.30abc	40.73 ± 0.38a

a) Values with the same letter down the column were not significantly different ($p > 0.05$).
b) Values are means of three determinations ±S.D. ($n = 3$).
WC – white trifoliate yam starch, YC – yellow trifoliate yam starch.

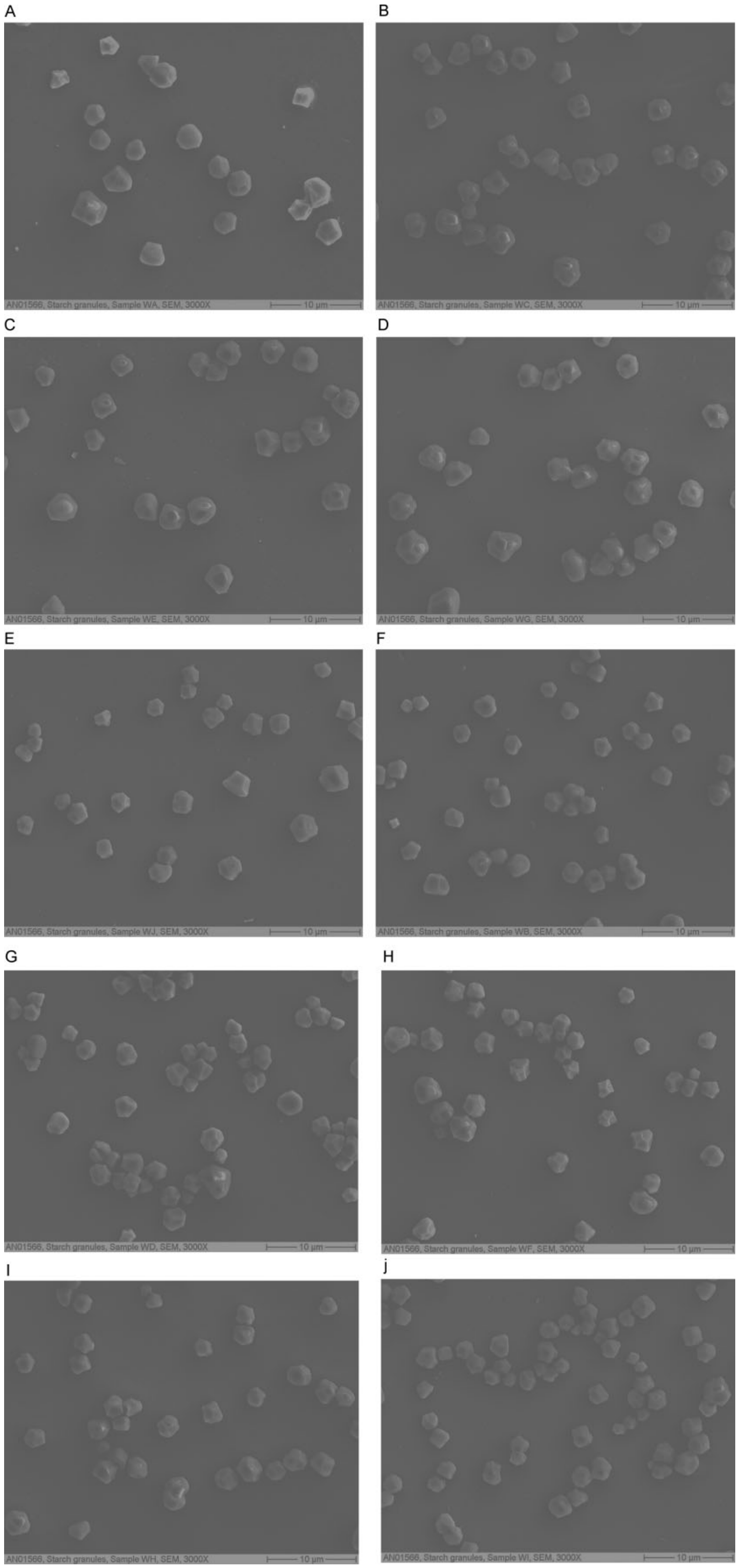

Figure 1. Morphological structures of white trifoliate yam starches harvested at; A-7 months, B-8 months, C-9 months, D-10 months E-11 months (white cultivar) F-7 months, G-8 months, H-9 months, I-10 months, J-11 months (yellow cultivar).

28.3 to 33.1% and white yam 20.3% [10, 29, 30]. Amylose content determination is influence by starch source, sample preparation, molecular structure of starch, harvesting periods, cultivar and methods of analysis [6, 31]. It 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 [10].

3.4 Starch content

The starch contents for the trifoliate yam are shown in Table 2. The value ranged from 40.73 to 63.34%. The least value was observed in yellow trifoliate yam harvested at 11 months while the highest value was in white cultivar harvested at 9 months. The starch contents of white cultivar were higher than those observed for the yellow trifoliate yam at varying periods. Starch contents increased slightly from 7 to 9 months in both cultivar and then decreased rapidly as harvesting period was prolonged. Increase in starch contents were observed for *D. alata* during growth by Huang et al. [30]. The starch values recorded for *D. alata* (81.8–85.3%) at different growing periods were higher than that of trifoliate yam. The variations in values may be due to harvesting periods, yam species and methods of analysis. Decrease in the starch contents of the two cultivars from 10 to 11 months may be due to sprouting and hydrolysis of starch. This occurs as a result of the action of diastase enzymes which break down the starch into smaller molecules (sugar). Afoakwa and Sefa-Dedeh [32] reported increase in the levels of sugars and cell wall polysaccharides constituents and increases in texture during storage of trifoliate yam tubers, with substantial decreases in moisture and starch contents. Panneerselvam and Jaleel [33] also reported rapid loss in starch contents of *D. esculenta* and *C. longa* from 6 to 10 week of storage to sprouting. Therefore, useable starch can be extracted from trifoliate yam tubers harvested at 9 months before the beginning of raining season. Starches are necessary to impart functionally desirable attributes to foods and are important ingredient for the food industry [34].

3.5 Swelling power

Swelling power of starches from white and yellow cultivars is shown in Fig. 3. The swelling power of trifoliate yam starches followed the same trend with other starches from other sources as reported by Riley et al. [10], Ikegwu et al. [35] and Yuan et al. [24]. Swelling power was found to increase with increasing temperature for all the starches from the two cultivars. There was a sharp increase in the swelling power of all the starches at 90°C. The white trifoliate yam starch harvested at 11 months had higher swelling power at 90°C while yellow cultivar starch harvested at 10 months had higher swelling power at 90°C. Swelling power is largely controlled by the strength and character of the micellar network within starch granules [36] and the extent of this interaction have been reported to be influenced by the amylose/amylopectin ratio [37, 38]. Amylose was reported to restrict swelling and that starch granules show complete swelling after amylose has been leached out of the granules [39]. Starch swelling capacity and AML have been associated to amount of amylose complexed with lipid, chain length of amylose, inter-

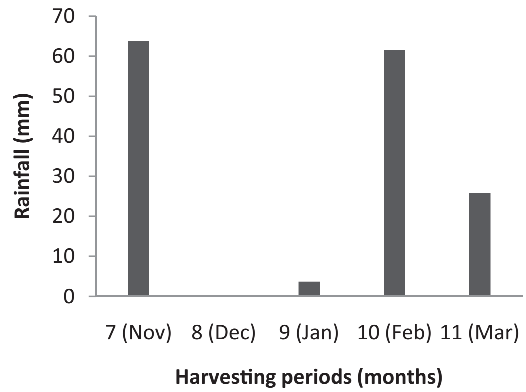

Figure 2. Cumulative monthly rainfall (mm) data for the experimental periods (November 2011–March 2012).

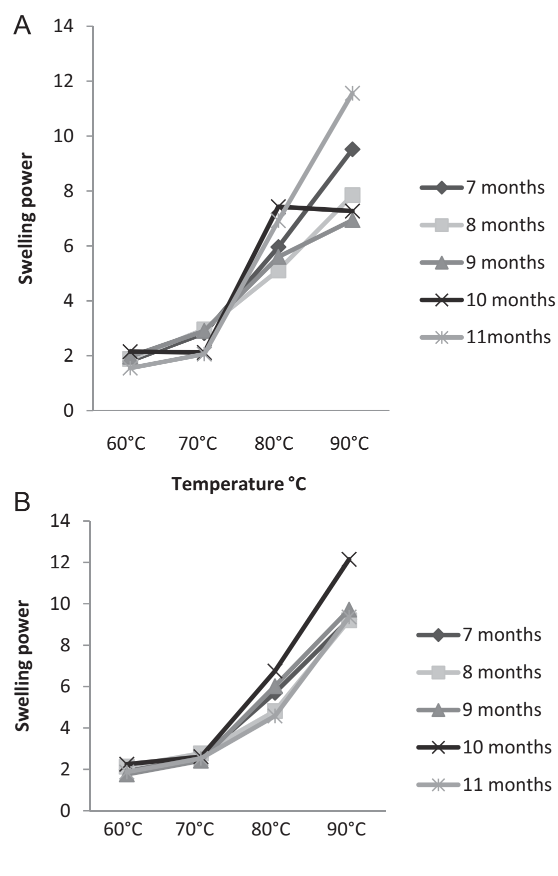

Figure 3. Effect of harvesting periods on the swelling power of white and yellow trifoliate yam starches; (A) white trifoliate yam starches, (B) yellow trifoliate yam starches.

chain interaction of amylose and amylopectin in the starch granules, and phosphate content [24, 40]. Swelling power is an indication of the water absorption index of the granules during heating and reflects the extent of the associative forces within the granules [41, 42].

3.6 Pasting properties

The pasting properties of the two cultivars of trifoliate yam starches are shown in Table 3. The highest peak viscosity (373.71 RVU) was in white trifoliate yam starch at 7 months and this decreased down with prolonged harvesting time. In the yellow cultivar, the starch extracted at 9 months had the highest peak viscosity (292.39 RVU). There was significant difference ($p>0.05$) in the peak viscosities of white trifoliate yam starch with the least value at 11 months. Decrease in the peak viscosities may be due to decrease in the starch contents. Sprouting of the tubers from the two cultivars occurred at 10 months due to the early rainfall (Fig. 2). The decrease in starch contents may be due to the activities of enzyme α-amylase which break down the starch into sugar as reported by Afoakwa and Sefa-Dedeh [32]. The activities of enzymes depend on temperature, moisture content, and environmental conditions of germination [43]. High peak viscosity observed at 7 months in the white cultivar indicates high swelling ability due to more rigid structure of starch granules as compared to the yellow cultivar. Within the cultivars, the starch samples at 8 months were more stable than the other starches at varying periods. The final viscosities of the two cultivars were high at 8 months signifying the ability of the starches to form viscous gel after cooking and cooling than others. The pasting properties observed were not in agreement with the findings of Nkala et al. [44], who observed slight difference in the viscosity parameters of *D. dumetorum* starch during the dry and wet seasons. Moorthy and Ramanujam [42] also reported insignificant change in the rheological properties of *D. alata*, *D. esculenta* and *D. rotundata* harvested at different maturity. Huang et al. [30] observed increase in peak (217.6–708.9 RVU) and final (394.8–710.7 RVU) viscosities in *D. alata* varieties during growth. The lower peak viscosities in the two trifoliate yam cultivars may be due to the smaller granule sizes observed in the starches. Holding strength, final viscosity and breakdown viscosity decreased with prolonged harvesting periods. Yellow trifoliate yam starch at 8 months had higher setback value (112.27 RVU) while the least was in white trifoliate yam starch at 9 months (50.34 RVU). The set back viscosities of trifoliate yam starches indicate lower tendency of the starches to retrogradation when compared to other starches from roots and tubers [30, 45]. The functional characteristics like viscosity, swelling power and solubility depend on a number of factors such as varietal variation, method of extraction, processing conditions and instruments used for analysis [42].

4 Conclusions

Harvesting periods did not have significant effect on the shape of the starch granules but had slight effect on the granule size of the trifoliate yam starches. White trifoliate yam tubers had higher starch yield than the yellow cultivar. Useable starch can be obtained from the two cultivars at 9 months. The starches from trifoliate yam would be more digestible than other roots and tubers due to their smaller granule sizes and lower amylose contents. Swelling power was also affected by harvesting periods, cultivars and temperature. Pasting properties revealed that white trifoliate yam starches harvested at 7–9 months could be used for products requiring high paste viscosity while others with low paste viscosities could be used in food formulation.

Table 3. Effect of harvesting periods on the pasting properties of white and yellow trifoliate yam starches[a),b)]

Cultivar	Harvesting period (months)	Peak viscosity (RVU)	Holding strength (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Pasting time (min)	Pasting temp (°C)
WC	7	373.71 ± 2.42e	156.58 ± 1.41e	217.14 ± 1.01e	228.50 ± 3.54c	71.92 ± 2.12cd	4.78 ± 0.02ab	49.36 ± 0.02a
	8	338.17 ± 2.83d	167.84 ± 0.83e	170.34 ± 2.00d	267.58 ± 1.41e	99.75 ± 2.23ef	5.14 ± 0.02ab	49.16 ± 0.01a
	9	299.48 ± 1.75e	137.42 ± 2.00a	162.21 ± 2.53d	187.75 ± 0.11b	50.34 ± 1.89a	4.96 ± 0.01ab	49.61 ± 0.01a
	10	222.67 ± 2.72b	92.84 ± 1.18b	129.84 ± 2.54c	177.67 ± 0.23b	84.84 ± 0.94de	4.58 ± 0.03ab	49.56 ± 0.02a
	11	199.77 ± 1.10a	77.68 ± 1.50a	121.94 ± 0.61c	149.84 ± 1.13a	72.01 ± 1.41cd	6.16 ± 1.12b	49.78 ± 0.03a
YC	7	278.35 ± 3.16c	154.19 ± 2.09e	124.16 ± 1.07c	240.06 ± 2.04cd	85.87 ± 0.05de	4.52 ± 0.02a	49.36 ± 0.05a
	8	232.21 ± 1.29b	135.42 ± 1.84cd	96.79 ± 2.55a	247.77 ± 2.12d	112.27 ± 2.85f	5.02 ± 0.14ab	49.18 ± 0.02a
	9	292.39 ± 2.17cd	136.59 ± 0.67d	155.79 ± 1.48d	194.69 ± 1.33b	58.11 ± 1.63abc	4.68 ± 0.01ab	49.04 ± 0.01a
	10	237.55 ± 1.66b	122.09 ± 2.00c	115.46 ± 2.66bc	190.59 ± 2.48b	68.50 ± 1.48bc	4.55 ± 0.02a	49.56 ± 0.01a
	11	200.81 ± 0.67a	99.34 ± 0.95b	101.47 ± 0.28ab	160.26 ± 1.29a	55.29 ± 1.53ab	4.97 ± 0.02ab	49.55 ± 0.03a

a) Values with the same letter down the column were not significant different ($p > 0.05$).
b) Values are means of three determinations ±S.D. ($n = 3$).
WC – white trifoliate yam starch, YC – yellow trifoliate yam starch.

This study represents an extract from the Ph.D research work of O. A. Abiodun at Department of Food Technology, Faculty of Technology, University of Ibadan.

The authors have declared no conflict of interest.

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