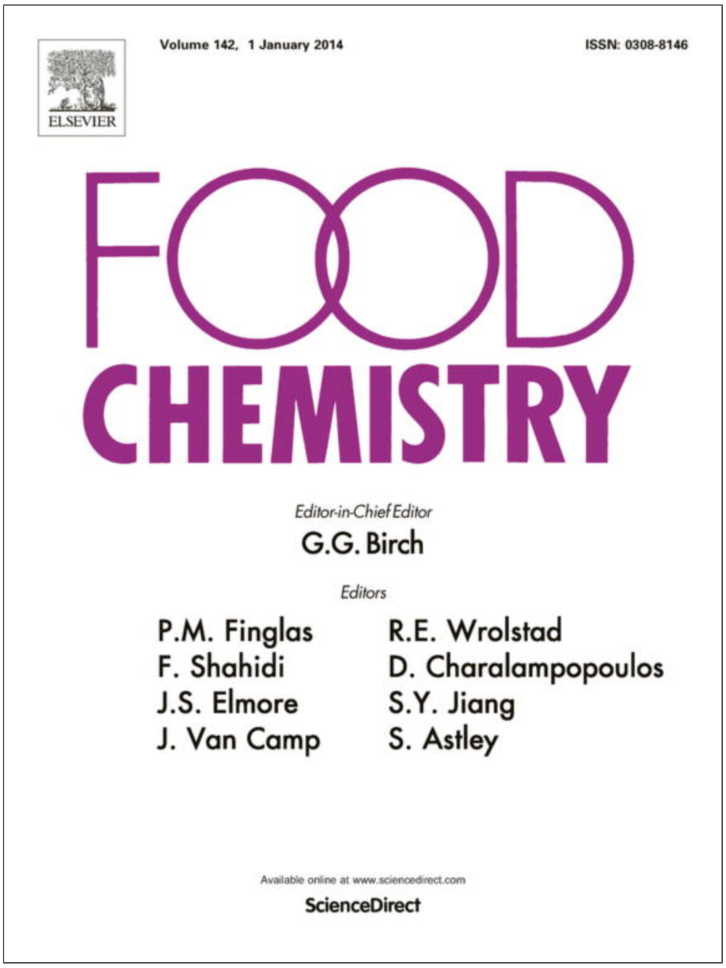
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Effect of harvesting periods on the chemical and pasting properties of trifoliate yam flour

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ABSTRACT

The effects of delayed harvesting on the chemical and pasting properties of trifoliate yam flour were studied. The tubers were harvested at 7, 8, 9, 10 and 11 months after maturity and were processed into flours. Chemical and pasting properties of the flours were determined. White trifoliate yam flour at 11 months was significantly different ($p < 0.05$) from other flours in dry matter and fibre contents but the lignin content (1.83%) was not significant different ($p > 0.05$) from yellow trifoliate yam flour at 11 months. Amylose and starch contents decreased while the sugar contents increased with harvesting periods. Yellow trifoliate yam flour had higher amylose at 10 months while the white trifoliate yam flour had higher starch at 9 months and sugar contents at 11 months. Potassium and sodium were the major minerals found in the yam with higher values in yellow trifoliate yam flours. Peak viscosity and breakdown decreased while the holding strength and final viscosities increased with harvesting periods. Harvesting trifoliate yam tubers at 7–9 months produced flour with high quality and prevents post harvest losses.

1. Introduction

Yam belongs to the genus *Dioscorea* (Family *Dioscoreaceae)* and is the second most important tropical root crop in West Africa, next to cassava (Opara, 1999). It is an important food in many tropical countries particularly in West Africa, South Asia and Caribbean, where it also has a social and cultural importance for about 300 million people throughout the world (Ettien et al., 2009). The varieties of yams grown in Nigeria are recognised by the range and colour of their leaves and tubers as well as by the direction of their stem twinning as they climb (Okigbo & Nwakammah, 2005). The genus *Dioscorea* includes about 600 species of which only six species are cultivated and consumed in Nigeria (Ike & Inoni, 2006; Okigbo, 2004). The cultivated species in Nigeria are the *Dioscorea rotundata* (White guinea yam), *Dioscorea cayenensis*, (Yellow guinea yam), *Dioscorea dumetorum* (trifoliate yam), *Dioscorea bulbifera* (aerial yam), *Dioscorea esculenta* (Chinese yam) and *Dioscorea alata* (water yam) (Ike & Inoni, 2006; Okigbo, 2004).

Trifoliate yam (*D. dumetorum*) is a lesser known yam among the yam species and is underutilized. Trifoliate yam tubers are known as three leaved yam, bitter yam and cluster yam. The plant is easily identifiable by its trifoliate compound leaf which twines in anticlockwise direction. The tubers are eaten during the time of famine or scarcity and are usually boiled with peel and eaten as boiled yam. Nutritionally, the tuber is superior to the commonly consumed yams, having high protein and mineral content (Martin, Treche, Noubi, Agbor, & Gwangwa, 1983).

Trifoliate yam tubers harden within 48 h after harvest and render them unsuitable for human consumption, even after long cooking (Afoakwa & Sefa-Dedeh, 2001). Only freshly collected tubers can be consumed locally and technological transformation of *D. dumetorum* was reported to be carried out promptly after harvest (Brillouet, Treche, & Sealy, 1981). Due to this reason, the tubers are left in the soil and harvested when needed for food. Although, the chemical, anti-nutritional, biochemical changes occurring during growth and storage of the tuber had been studied (Afoakwa & Sefa-Dedeh, 2001; Afoakwa & Sefa-Dedeh, 2002; Medoua, Mbome, Agbor-Egbe, & Mbofung, 2005a, 2007; Treche & Agbor-Egbe, 1996), but there is dearth of information on the effect of keeping the yam tubers in the ground after maturity. However, methods of storing yam tubers had been reported to vary from delayed harvesting, storage in simple piles or clamps to storage in buildings specially designed for that purpose, and application of sophisticated modern techniques (Igbeka, 1985; Ofor, Oparaeke, & Ibeawuchi, 2010). Ofor et al. (2010) reported losses in yam tubers stored using traditional methods as a result of uncontrolled temperature conditions thereby increasing the rate of respiration in the yam. However, the effect of delayed harvesting on the chemical and pasting properties of trifoliate yam flour is necessary as these enable us to know the changes occurring in the yam flours during these periods. Processing of

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trifoliate yam into flour curbs wastage, boost utilisation and improve the economic values of the yam. This paper aimed at comparing the effect of delayed harvesting on the chemical and pasting properties of flours from the two major cultivars (yellow and white) of trifoliate yam.

2. Materials and methods

2.1. Materials

The trifoliate yam setts of two cultivars (white and yellow) were collected from Esa-Oke farm settlements, Osun State, Nigeria.

2.2. Methods

2.2.1. Samples preparation

Trifoliate yam setts weighing 850–900 g were planted in mounds with 10 per row and spacing of 1 × 1 m on a plot of land. Thirty samples were planted per each cultivar. The planting was done on 20th March 2010 and sprouting of some of the yam setts occurred on 26th of April 2010. These trifoliate yam setts were marked and used for the study. The plot of land was weeded manually at a month interval after planting. There was no application of chemicals such as fertiliser, pest control or herbicides. The yam tubers were harvested at 7, 8, 9, 10 and 11 months after maturity starting from November 26th 2010–March 26th 2011. The experiment was repeated in November 20th 2011–March 20th 2012.

2.2.2. Preparation of flour

The freshly harvested yam tuber was washed, drained and peeled. The peeled tuber was sliced and dried in the hot air oven at 60 °C for 48 h. The dried chips were milled into flour with hammer mill and sieved with 600 μm sieve size. The flour samples were sealed in polythene bag.

2.2.3. Dry matter content determination

This was carried out by using the procedure of A.O.A.C method 925.09 (1990). The moisture cans were cleaned and dried in oven for one hour at 100 °C and were allowed to cool in the dessicator for 45 min. Then 5 g of sample were weighed in the dried moisture can. The cans were placed in oven overnight for 22–24 h at 105 °C. The sample cans were removed in oven and cooled in dessicator for 45 min and weighed.

$$\%\,\mathrm{MC} = \frac{\text{Initial weight of can} + \text{sample} - \text{final weight of can} + \text{sample}}{\text{Sample weight}} \times 100$$

$$\text{Dry matter } (\%) = 100 - \mathrm{MC}$$

2.2.4. Ash content determination

This was carried out by using the procedure of A.O.A.C method 923.03 (1990). The crucible used were dried in oven for one hour at 100 °C and allowed to cool in the dessicator. Then 3 g of sample were weighed into the dried weighed crucible. The crucible was placed in hot plate for one hour in order to burn the sample. The crucible was then transferred into the muffle furnance for six hours at 600 °C. The sample was removed in furnace, cooled in dessicator and weighed.

$$\%\,\mathrm{Ash} = \frac{\text{Weight of empty crucible} + \text{sample} - \text{weight after ashing}}{\text{Sample weight}} \times 100$$

2.2.5. Crude fibre determination

Sample (1 g) was weighed into 500 ml flask and 100 ml of TCA digestion reagent were added. This was allowed to boil and reflux for exactly 40 min counting from the time boiling started. The flask was removed from the heater, cooled a little bit and filtered through no. 4 Whatman filter paper of known weight. The residue was washed six times with hot water and once with industrial spirit. The filter paper was folded and put in porcelain dish of known weight. It was dried overnight at 105 °C in the oven. This was removed, cooled in the dessicator for 45 min and weight was recorded. The sample and filter paper in the dish were burnt on hot plate for about one hour before transferring to muffle furnance at 600 °C for 5 h. After ashing the dish was cooled in the dessicator and weighed (AOAC method 962.09E, 1990).

$$\%\ \text{Crude fibre} = \text{Different in weight} \times 100$$

2.2.6. Determination of lignin

Flour sample (2.5 g) were treated four times with 25 ml 1% (v/v) 11 N HCl in methanol for 1 h under continuous stirring and centrifuged at 2000 rpm for 10 min. The residue obtained was then mixed with 100 ml of 12 M sulfuric acid and hydrolyzed for 3 h at ambient temperature under stirring. The solution was then diluted with distilled water to obtain 1 M H_2SO_4, and heated at 100 °C for 2.5 h with continuous shaking, cooled, vacuum filtered through an acid-treated 0.45 μm Millipore HVLP filter, and rinsed with hot distilled water and acetone. The filter containing lignin was air-dried at 60 °C overnight and weighed. Results were expressed as g lignin per 100 g sample dry weight (Medoua, Mbome, Agbor-Egbe & Mbofung, 2005b) and converted to percentage ligin.

2.2.7. Mineral contents

Flour sample (0.5 g) was weighed into a clean ceramic crucible. A blank was prepared with empty crucible. The crucible was placed in a muffle furnace at 500 °C for 4 h. The sample was allowed to cool down in the oven after which it was removed carefully. The ashed sample was poured into already labelled 50 ml centrifuge tube. The crucible was rinsed with 5 ml of distilled water into the centrifuge tube. The crucible was rinsed again with 5 ml of aqua regia. This was repeated to make a total volume of 20 ml. The sample was mixed properly and centrifuged (IEC Centra GP8) for 10 min at 301.86 g. The supernatant was decanted into clean vials for mineral determination. The absorbance was read on atomic absorption spectrophotometer (Buck Scientific Model 200A) at different wavelength for each mineral element (Cu-324.8, Zn-213.9, Ca-422.7, Fe-248.3, Mg-285.2, Mn-279.5, Na-589 and K-766.5 nm) (Novozamsky, Houba, Van, & Van, 1983).

2.2.8. Amylose content

Flour 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. 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 (Juliano, 1971).

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:

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

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

where

F = Concentration factor from standard
A = Absorbance of solution
DF = Dilution factor.

2.2.9. Free sugar and starch contents determination

Free sugar was extracted from the flour with hot ethanol while the starch was hydrolyzed to its monosaccharide with perchloric acid. The sugar was quantified colorimetrically using phenol and sulphuric acid. Sugar obtained from the hydrolysis of the starch was converted to starch by multiplying by a factor of 0.9.

Flour sample (25 mg) was weighed into a centrifuge tube and wetted with 1 ml of 95% (v/v) hot ethanol at room temperature. Then, 2.0 ml of distilled water and 10 ml of ethanol was added. The mixture was vortexed and centrifuged for 10 min at 2000 rpm. The supernatant obtained was decanted into a test-tube and made up to 20 ml extract before being used for sugar analysis. To 0.2 ml of the extract, 0.8 ml of distilled water and 0.5 ml of 5% phenol was added. The mixture was vortexed before subsequent addition of 2.5 ml of conc. H_2SO_4. The absorbance of the solution was read on a spectrophotometer (Milton Roy Spectronic 601) at 490 nm after it cooled. The residue, after decantation of supernatant, was hydrolyzed 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 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 was mixed thoroughly and then allowed to cool before being read at 490 nm on the spectrophotometer (Milton Roy Spectronic 601) (Mcready, 1970). A calibration standard curve of absorbance against glucose concentration was plotted from which the percentage sugar and starch in the sample was calculated.

Calculation:

$$\% \text{ Sugar} = \frac{(A - I) \times DF \times V}{B \times W \times 10^6} \times 100$$

$$\% \text{ Starch} = \frac{(A - I) \times D.F \times V \times 0.9}{B \times W \times 10^6} \times 100$$

where

A = Absorbance of sample
I = Intercept of standard curve
DF = Dilution factor based on the aliquot of sample extract taken for assay.
V = Total extract volume
B = Slope of the standard curve
W = Sample weight.

2.2.10. 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) was calculated using formular below:

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

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

where

A = 3 g
S = Calculated sample weight for RVA
M = Moisture content of the sample
W = 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 triplicates with replication. The mean and standard deviation of the data obtained were calculated. The data were evaluated for significant differences in their means with Analysis of Variance (ANOVA) ($p < 0.05$). Differences between the means were separated using turkey test as packaged by SPSS (17.0) software.

3. Results and discussion

3.1. Effect on dry matter contents

Table 1 showed chemical composition of white and yellow cultivars. The dry matter contents ranged from 31.85% to 45.34%. The white trifoliate yam tuber had higher dry matter than the yellow cultivar. White trifoliate yam flour at 10 months was significant different ($p < 0.05$) from other flour in the dry matter composition. Dry matter increased till 10 months and then decreased slightly at 11 months for both cultivars. The dry matter was high and was in contrary to the report of Treche & Agbo-Egbe (1996) and Afoakwa & Sefa-Dedeh (2002) for trifoliate yam tubers. Adeyeye, Arogundade, Akintayo, Aisida, and Alao (2000) observed lower dry matter (25.7%) in both yellow and white trifoliate yam tubers. The dry matter contents reported by Dje, Dabonne, Guehi, and Kouame (2010) and Kouakou, Dabonne, Guehi, and Kuoame (2010) for two species of white yam were similar (38.28–45.59%) to the values obtained for trifoliate yam flour. Onwueme & Charles (1994) reported high percentage of moisture in yam tuber during tuber development and reduction in the moisture contents as the tuber approaches maturity. The reduction in the dry matter at 11 months for both cultivars may be due to sprouting of the tubers due to rainfall and this lead to depletion of the tuber carbohydrate as a

Table 1
Effect of harvesting periods on the chemical composition of trifoliate yam.

Cultivar	Harvesting periods	Dry matter (%)	Ash (%)	Fibre (%)	Lignin (%)
White	7	35.36 ± 0.32i	2.42 ± 0.06b	2.05 ± 0.09cde	0.22 ± 0.01e
	8	41.90 ± 0.12f	2.83 ± 0.06ab	2.18 ± 0.26cde	0.30 ± 0.05e
	9	43.99 ± 0.36c	4.08 ± 0.87a	2.52 ± 0.04bcd	0.42 ± 0.09de
	10	45.34 ± 0.10a	3.30 ± 0.05ab	2.77 ± 0.17bc	1.07 ± 0.23bc
	11	44.84 ± 0.19b	3.11 ± 0.15ab	3.70 ± 0.28a	1.83 ± 0.08a
Yellow	7	31.85 ± 0.11j	2.50 ± 0.07ab	1.58 ± 0.13e	0.19 ± 0.01e
	8	38.78 ± 0.09 h	3.84 ± 0.21ab	1.89 ± 0.03de	0.20 ± 0.01e
	9	41.94 ± 0.21e	2.57 ± 0.13ab	2.17 ± 0.24cde	0.50 ± 0.07de
	10	42.38 ± 0.26d	2.94 ± 0.91ab	2.69 ± 0.13bc	0.84 ± 0.08 cd
	11	39.39 ± 0.14 g	2.43 ± 0.07b	3.35 ± 0.49ab	1.39 ± 0.25ab

Values with the same letter down the column were not significant different ($p > 0.05$).

result of shoots growth (Onwueme & Charles, 1994). Dry matter of trifoliate yam was affected by the season and environmental conditions during harvesting (Fig. 1).

3.2. Effect on ash and crude fibre contents

Ash contents ranged from 2.42% to 4.08%. The ash contents of the white trifoliate yam flour were higher than yellow cultivar. There were increase in the ash contents of the two cultivars till 9 months and a decrease in ash contents till 11 months. White trifoliate yam flour had higher ash content (4.08%) at 9 months. This value was significantly different ($p < 0.05$) from white trifoliate yam flour at 7 months and yellow trifoliate yam flour at 11 months. The values obtained were slightly higher than the range 0.68–2.56% reported for yam species (Degras, 1993). Meduoa et al. (2005a) observed significant increase in ash contents of yellow cultivar of *D. dumetorum* after storage. The ash contents at varying harvesting periods were comparable to the values 1.51–3.07% obtained by Kouakou et al. (2010) for water yam flours.

The crude fibre contents of the two trifoliate yam flour ranged from 1.58% to 3.70%. The crude fibre contents increased appreciably till 11 months in both cultivars. The crude fibre content of white trifoliate yam flour at 11 months was not significantly different ($p > 0.05$) from yellow cultivar at 11 months. Treche & Agbo-Egbe (1996) reported higher crude fibre values of 3.5–4.2% for white yam trifoliate yam flours harvested at 7–10 months. The results of the crude fibre contents obtained were within the values reported for different yam species (Adeyeye et al., 2000) and slightly higher than *D. dumetorum* (0.60–2.44%) obtained by Afoakwa & Sefa-Dedeh (2001). Polycarp, Afoakwa, Budu, and Otoo (2012) also reported 2.10% and 3.47% crude fibre contents for white and yellow trifoliate yam flours respectively. Hardening process occurred in the tuber despite the underground storage and this can be seen in the values of the crude fibre contents of the flours. Hardening of the tuber results in thickening of the cell wall parenchyma, extended cooking time, impaired cooked tuber texture and taste (Medoua et al., 2007; Treche & Agbor-Egbe, 1996) and this may lead to increase in the fibre contents of the flour. The variation in crude fibre may be due to the cultivar, time of harvesting and methods of analysis used to quantify the nutrient.

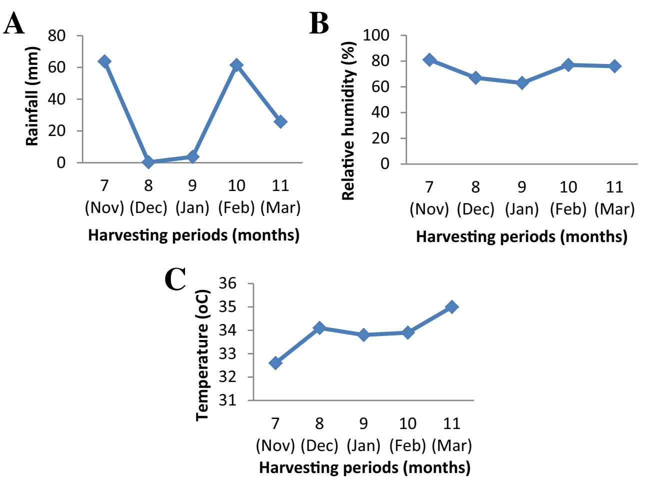

Fig. 1. Environmental conditions for experimental periods. (A) Cummulative monthly rainfall, (B) monthly mean relative humidity (C) monthly mean temperature.

3.3. Effect on lignin

Lignin contents of trifoliate yam flours observed ranged from 0.19% to 1.83%. The values increased with prolonged harvesting periods in both cultivars. White trifoliate yam flour had higher lignin content at 11 months but the value was not significantly different ($p > 0.05$) from the yellow trifoliate yam flour at 11 months. Moreover, no significant difference ($p > 0.05$) exists between the flours at 7–9 months in both cultivars. The white trifoliate yam flour had higher lignin contents than the yellow trifoliate yam flour at 7, 8, 10 and 11 months. This corroborates the findings of Afoakwa & Sefa-Dedeh (2001) that white cultivar had higher lignin, cellulose and hemicelluloses contents than the yellow cultivar. Brillouet et al. (1981) reported increase in lignin values of *D. dumetorum* tubers from 0.30% to 0.72% during storage. Likewise, Afoakwa & Sefa-Dedeh (2001) and Medoua et al. (2005b) observed increase in lignin contents of white and yellow *D. dumetorum* during storage. Storing trifoliate yam tubers in the ground for a long time after maturity had effect on the cell wall components of the tubers. Lignin, which is part of the cell wall components increased with delayed harvesting and may result in hardening of the tuber. Hardening had been reported to affect the cooking and textural properties of trifoliate yam tubers (Afoakwa and Sefa-Dedeh, 2001).

3.4. Effect on amylose, starch and sugar

The effect of delayed harvesting on the amylose, sugar and starch contents of trifoliate yam flour are presented in Table 2. Amylose contents of yellow trifoliate yam flours at different periods were higher than white trifoliate yam flour. It increased with harvesting periods in yellow cultivar until 10 months (15.89%) and then decline. But the trend was different in the white cultivar, the highest being at 9 months (15.38%). Yellow trifoliate yam flour at 10 months was significantly different ($p < 0.05$) from other flours. Amylose contents of trifoliate yam flours were lower than water yam (Barbados cultivar) (23.01%) and white-yellow yam (25.6 mg/100 g) as observed by Brunnschweiler et al. (2005) and

Table 2
Effect of harvesting periods on the amylose, starch and sugar contents (%) of trifoliate yam flour.

Cultivar	Harvesting periods (months)	Amylose (%)	Starch (%)	Sugar (%)
White	7	13.86 ± 0.12f	54.27 ± 0.17a	1.93 ± 0.08e
	8	13.93 ± 0.30f	54.95 ± 0.12a	2.72 ± 0.06de
	9	15.38 ± 0.15bc	55.15 ± 0.10a	3.21 ± 0.31 cd
	10	14.30 ± 0.09e	43.94 ± 0.33d	5.25 ± 0.82b
	11	14.13 ± 0.16ef	38.91 ± 0.11e	7.27 ± 0.16a
Yellow	7	14.68 ± 0.10d	47.63 ± 0.10c	1.60 ± 0.06e
	8	15.40 ± 0.21bc	46.79 ± 0.15c	2.42 ± 0.10de
	9	15.51 ± 0.42b	51.64 ± 0.11b	2.60 ± 0.14de
	10	15.89 ± 0.11a	47.23 ± 0.08c	4.07 ± 0.09bc
	11	15.20 ± 0.10c	31.34 ± 0.20f	6.70 ± 0.29a

Values with the same letter down the column were not significant different ($p > 0.05$).

Riley, Wheatley, and Asemota (2006). Amylose is considered as one of the most important quality factors of yam flour since it is known to affect water absorption and textural properties of yam flour and the resultant products. It was indicated to affect gelatinization, retrogradation, swelling power and enzymatic susceptibility of starches (Gerard et al., 2001; You and Izidorczyk, 2002).

There was no significant difference ($p > 0.05$) in the starch contents of white trifoliate yam flours at 7–9 months. Starch contents increased from 7 to 9 months and later decreased till 11 months due to hydrolysis of starch into sugar. The starch contents of white trifoliate yam flours were higher than the yellow flours at different harvesting periods. Starch contents of trifoliate yam flours were low when compared to other yam species. Higher starch contents were reported for *D. alata* and *D. rotundata* (Wanasundera & Ravindran, 1994; Ayernor, 1985).

Increase in sugar contents of trifoliate yam flours was observed till 11 months. The white trifoliate yam flour had higher sugar contents at different harvesting periods than the yellow trifoliate yam flours. White trifoliate yam flour at 11 months had the highest value (7.27%) but the value was not significantly different ($p > 0.05$) from yellow trifoliate yam flour at 11 months. Increase in the sugar contents with harvesting periods may be as a result of the sprouting in which the amylase enzymes produced hydrolyzed the starch molecules into the smallest molecules (sugar). Storage of yam after harvesting was also reported to leads to reduction in moisture, starch content and increase in sugars and structural polysaccharides (Afoakwa & Sefa-Dedeh, 2001). High sugar concentrations decrease the rate of starch gelatinization, the peak viscosity, and gel strength. Sugars decrease gel strength by exerting a plasticizing action and interfering with the formation of junction zones (Roy & James, 1985).

3.5. Effect of delayed harvesting on mineral compositions

The mineral compositions of trifoliate yam flours are shown in Table 3. Potassium was the most abundant mineral content (140.67–165.37 mg/kg) in trifoliate yam flour followed by sodium contents. This agrees with the findings of Polycarp et al. (2012). Sodium and potassium contents increased to 9 months and decreased again. The highest sodium content was in yellow flour at 9 months but the value obtained was not significantly different ($p < 0.05$) from yellow flour at 8 and 10 months. Likewise no significant differences ($p < 0.05$) was observed in potassium contents of white and yellow flours at 8 and 9 months. The values decreased with delayed harvesting periods. Yellow trifoliate yam flour had higher calcium content at 8 and 9 months but they were not significantly different ($p < 0.05$) from white trifoliate yam flour at 8 months. Magnesium contents ranged from 49.51 to 58.35 mg/kg. Lower values were observed in the flours obtained at 7 months in both cultivars and 11 months in yellow cultivar. The highest value was in white trifoliate yam flour obtained at 9 months but no significant differences ($p < 0.05$) existed in the cultivar at 8, 10 and 11 months, and 9–10 months in the yellow cultivar. Manganese contents of yellow trifoliate yam flours were higher than that of white flours. There was no significant differences ($p < 0.05$) in the yellow trifoliate yam flour obtained at 8–10 months. Also, no significant differences ($p < 0.05$) existed in Iron (Fe) contents of yellow flour at 8–11 months and white trifoliate yam flour at 8–9 months. In all the minerals evaluated, yellow trifoliate yam flour had higher values except in magnesium. Lower mineral contents were observed for yam flours by Bhandari, Kassai, and Kawabata (2003) and Polycarp et al. (2012) for *D. bulbifera.* Mineral compositions of yam are affected by season, species, soil type and cultural practices adopted during planting.

3.6. Effect of delayed harvesting on the pasting properties of trifoliate yam flour

According to the RVA patterns, the pasting behaviours of trifoliate yam flours were slightly affected by harvesting periods (Table 4). White trifoliate yam flour at 7 months gave the highest peak viscosity (227.04 RVU) and the least value was at 11 months. There was no significant difference ($p > 0.05$) in the values obtained at 7–10 months in white and yellow cultivars. Yellow cultivar harvested at 7 months and white cultivar harvested at 10 months have higher values in holding strength but was not significantly difference ($p > 0.05$) from each other. This showed that the flours could withstand high temperature conditions than other flours. White trifoliate yam flour at the earlier harvesting periods showed a higher breakdown values than those harvested at latter stage. On cooling, the viscosities of the white trifoliate yam flours

Table 3
Effect of harvesting periods on the mineral composition (mg/kg) of yellow trifoliate yam flour.

Cultivar	Harvesting periods (months)	Na	K	Ca	Mg	Mn	Fe
White	7	66.05 ± 0.07f	153.61 ± 0.86cde	51.11 ± 1.11e	49.51 ± 0.40c	0.35 ± 0.02e	0.48 ± 0.01 cd
	8	85.12 ± 1.80bcd	160.67 ± 0.95ab	58.39 ± 0.09ab	55.75 ± 0.73a	0.49 ± 0.01c	0.69 ± 0.01ab
	9	89.46 ± 1.53bc	163.19 ± 1.26a	56.98 ± 0.30b	58.35 ± 1.13a	0.41 ± 0.01d	0.68 ± 0.04bcd
	10	73.27 ± 1.21ef	155.94 ± 1.96bcd	51.78 ± 0.62c	55.43 ± 0.98a	0.31 ± 0.01e	0.55 ± 0.01bcd
	11	75.97 ± 0.40def	151.72 ± 0.56 cde	45.78 ± 0.15f	58.44 ± 0.35a	0.32 ± 0.03e	0.44 ± 0.16d
Yellow	7	82.40 ± 1.86cd	156.54 ± 0.76bcd	53.45 ± 0.61d	48.26 ± 0.81c	0.42 ± 0.01d	0.61 ± 0.01bcd
	8	106.91 ± 1.06ab	165.37 ± 0.54a	60.19 ± 0.88a	54.99 ± 0.16a	0.56 ± 0.01ab	0.87 ± 0.02a
	9	114.22 ± 1.52a	162.02 ± 1.13a	60.50 ± 0.69a	56.31 ± 0.44a	0.57 ± 0.01a	0.86 ± 0.01a
	10	109.64 ± 0.52ab	151.18 ± 0.25cde	54.31 ± 0.44c	54.40 ± 0.42ab	0.52 ± 0.01 cd	0.71 ± 0.01ab
	11	98.28 ± 1.43bc	149.67 ± 0.60e	53.74 ± 0.24d	50.06 ± 0.08bc	0.51 ± 0.01 cd	0.67 ± 0.01bcd

Values with the same letter down the column were not significant different ($p > 0.05$).

Table 4
Effect of harvesting periods on the pasting properties of trifoliate yam flour.

Cultivar	Harvesting period	Peak viscosity (RVU)	Holding strength (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Pasting time (min)	Pasting Temp (°C)
White	7	227.04 ± 2.42a	129.30 ± 0.53 cd	97.75 ± 1.83a	192.88 ± 1.83def	63.59 ± 1.30bc	4.79 ± 0.00b	48.81 ± 0.92a
	8	215.75 ± 1.84a	149.21 ± 2.30b	66.54 ± 2.53b	207.88 ± 1.94cdef	58.67 ± 0.35bc	4.91 ± 0.06b	48.71 ± 0.07a
	9	210.21 ± 1.95a	155.5 ± 2.12b	54.71 ± 2.30b	236.09 ± 0.12bc	80.59 ± 2.00ab	4.88 ± 0.02b	48.61 ± 0.21a
	10	200.88 ± 1.77ab	173.33 ± 1.24a	27.55 ± 0.53d	284.42 ± 1.01a	111.09 ± 1.17a	5.23 ± 0.07ab	48.86 ± 0.14a
	11	162.48 ± 1.87d	129.72 ± 1.38 cd	32.76 ± 1.25 cd	243.08 ± 1.11abc	113.36 ± 2.73a	5.73 ± 0.61a	48.76 ± 0.02a
Yellow	7	199.25 ± 1.23abc	180.84 ± 2.18a	18.42 ± 1.95d	265.13 ± 3.95ab	84.30 ± 1.24ab	5.18 ± 0.14ab	48.61 ± 0.35a
	8	174.09 ± 1.13bcd	143.54 ± 1.42bc	30.55 ± 1.71 cd	183.67 ± 1.95f	40.13 ± 2.54c	5.21 ± 0.11ab	48.81 ± 0.07a
	9	172.88 ± 1.31bcd	124.55 ± 1.77d	48.33 ± 1.54bc	185.30 ± 1.83ef	60.75 ± 0.06bc	4.89 ± 0.04b	49.11 ± 0.05a
	10	171.29 ± 2.13 cd	149.67 ± 0.83b	21.63 ± 2.30d	231.25 ± 1.19bcd	81.59 ± 1.36ab	5.48 ± 0.05ab	48.91 ± 0.07a
	11	166.84 ± 2.17d	144.67 ± 1.23b	22.17 ± 1.07d	206.86 ± 1.62cdef	62.19 ± 2.62bc	5.51 ± 0.00ab	48.96 ± 0.00a

Values with the same letter down the column were not significant different ($p > 0.05$).

decreased at 7 and 8 months but the viscosities of other flours increased rapidly indicating large number of intermolecular hydrogen bonds that were formed, resulting in gel formation at lower temperatures (Huang, Lin & Wang, 2006). Higher setback and pasting time values were observed for white cultivar harvested at 10 and 11 months. Likewise, the minimum time to cook the yellow flour harvested at 10 and 11 were higher than other flour. There was no significant difference ($p > 0.05$) in the pasting temperatures of all the flour samples.

4. Conclusion

White trifoliate yam flour had higher dry matter, starch and sugar contents at different harvesting periods than the yellow cultivar. Increase in lignin contents indicate changes in the structural composition of the tuber which could result in significations of the cell wall constituents of the tubers leading to hard to cook process. Moreover, the pasting properties of the flours were also affected by delayed harvesting. However, storing trifoliate yam tubers in the ground could only protect the tubers to a certain periods and when it exceeds these periods, wastage would occur. Therefore, storing the yam till 9 (January) months before the next season rainfall is advisable to avoid post harvest losses.

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