

Food Quality Changes in Water Yam (*Dioscorea Alata*) During Growth and Storage

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ABSTRACT— *The changes in food quality characteristics during growth and storage of five varieties of D. alata were studied. Tubers were harvested at 5, 7 and 9 months after planting (MAP) and were stored for a period of 5 months in a conventional yam barn. Moisture content decreased significantly ($p < 0.05$) during growth (73.43 to 70.18%) and throughout the storage period (70.18 to 64.64%). Sugar contents increased from 5MAP to end of storage period (4.04 to 6.79%). Starch content increased from 67.01 to 73.79% at 9MAP but decreased to 65.35% at the end of storage. The changes are due to photosynthetic materials accumulation during growth period, dehydration and breakdown of starch to sugars due to respiration during storage. Unlike amylose, swelling power decreased during growth but increased (6.26-9.02%) in storage. Pasting viscosities increased throughout the growth period to the end of storage (Peak-206.00 to 259.18; Final viscosity-249.80 to 304.80; setback-57.06 to 83.90 RVU). The increases in dry matter and sugar contents, swelling power and pasting viscosities of stored D. alata tubers would have significant improvement in their organoleptic and textural properties. The study has shown that time of harvesting and length of storage of D. alata tubers significantly impacts on the food quality characteristics.*

Keywords: water yam, food quality, maturity, storage

1. INTRODUCTION

Yam is the third most important tropical root and tuber crop after cassava and sweetpotato.¹ Yams have both economic and social values for millions of people comprising rural poor producers, processors and consumers especially in West Africa.²

The effective growth duration of yams ranges from 6 to 12 months (depending on the variety), calculated from the day of shoot emergence until the time of senescence of the leaves.³ Maturity of the yam tuber influences its food quality even though it has not been clearly defined in yams. The tubers are reported to be ready for harvesting at 6 months after vine senescence³ but in the traditional setting, yam maturity is simply measured by the dryness of vines by farmers.⁴

After harvesting, yam tubers are stored to preserve parts for consumption, for vegetative propagation, or preserved for the market when prices are higher. The yam tuber has an important adaptive mechanism called dormancy, a physiological rest period without obvious external signs of biochemical activity, which allows it to be stored for relatively longer periods than other root and tuber crops⁵ thereby ensuring food security at times of general food scarcity.

Research has shown that the developmental stage or harvest time of potatoes had effect on starch properties.^{6,7} Significant changes in rheological properties and amylase enzyme activities have been reported in *D. dumeterum* tubers after harvesting.⁸ Several physiological and biochemical changes are known to occur during storage of yam tuber which may depreciate or enhance the food quality.⁹⁻¹¹ In the case of *D. alata*, there is a general perception that food quality characteristics of the tubers improve upon storage (Personal communication). This study aims to investigate the impact of time of harvesting (maturity) and storage of *D. alata* tubers on food quality characteristics. To achieve this aim, tubers of *D. alata* varieties were processed into flour and the physicochemical (moisture, protein, sugar, starch, amylose and swelling power) and pasting characteristics determined.

Table 1: Yam varieties from IITA used for the studies

Serial number	Species/variety	Local/source name	Country of origin	Nature of variety
	<i>D. alata</i>			
1	TDa 98-159	Ngoul Kaude	Chad	Landrace
2	TDa 99/00395	-	Nigeria	Breeder's line
3	TDa 291	Forastero	Puerto Rico	Landrace
4	TDa 297	UM 680	Nigeria	Landrace
5	TDa 93-36	Agbo	Nigeria	Landrace

2. MATERIALS AND METHODS

2.1 Source of Materials

Five varieties of *D. alata* (Table 1.0) were obtained from experimental plots of yam breeding programme at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The varieties were harvested after 5, 7 and 9 months after planting.

2.2 Sampling and Experimental Procedure

Three healthy tubers were randomly picked out of the lot at each harvest. The tubers were washed, peeled and cut into small pieces (cubes), thoroughly mixed, dried and processed to flour for physicochemical and pasting analysis. The remaining healthy tubers harvested at 9 months after planting were packed in wooden boxes and stored on shelves in a conventional open-air yam barn (IITA yam barn, temperature 28.1 ± 3.5 °C, relative humidity $53.8 \pm 21.5\%$) for a period of 5 months. Three tubers per variety were randomly picked at the end of the first Month After Harvesting (MAH), 3rd MAH and 5th MAH, processed to flour and physicochemical/pasting properties determined. The tubers were washed, peeled and cut into small pieces (cubes), thoroughly mixed, dried and processed to flour for physicochemical and pasting analysis.

2.3 Laboratory Analysis

2.3.1 Preparation of flour for laboratory analysis:

Yam tubers were washed, peeled and diced into cubes and dried in an air convection oven at 60 °C for 72 hr. Dried chips were milled into fine flour and packaged in polythene whirl-pack, and stored at -20 °C for laboratory analyses.

2.3.2 Determination of Moisture and dry matter contents

The moisture and dry matter contents of the samples were determined using standard AOAC¹² methods.

2.3.3 Determination of Protein content

This was carried out using HACH¹³ method by placing 0.20 g of the sample, concentrated sulfuric acid, peroxide and one tablet catalyst into a digestion tube and digesting the mixture at 375 °C for 3 hr. Distilled water was added to digest to bring the volume to 75 ml; it was covered with paraffin, and mixed thoroughly. One ml of the mixture was pipetted into 25 ml volumetric flask; 3 drops each of mineral stabilizer and polyvinyl alcohol solution were added and made up to 25 ml with distilled water. One (1) ml Nessler reagent was added for color development. Absorbance was read at 460 nm using HACH spectrophotometer (HACH Company, Loveland, Colorado, USA, Model, DR /3000) to determine the concentration of nitrogen. Protein content was calculated using a factor of 6.25.

2.3.4 Determination of starch and total sugar contents

The starch and total sugar contents were determined using a colorimetric method by Dubois.¹⁴ Absorbance was read at 490 nm using a spectrophotometer (model Spectronic 601, Milton Roy Company, USA).

2.3.5 Determination of amylose content

This was determined using the method of Juliano¹⁵ involving the preparation stock iodine solution. Absorbance was read using spectrophotometer (model Spectronic 601, Milton Roy Company, USA) at 620 nm. A blank was used to standardize the spectrophotometer.

2.3.6 Determination of swelling power

The method of Leach¹⁶ was used. Swelling power was expressed as the swollen sediment weight (g) per g of dry flour that dissolved molecularly after sample was heated in water between 85 and 85 °C.

2.4 Statistical Analysis

The general linear model (GLM) procedure of SAS¹⁷ version 9.1 was used to evaluate duplicated sample data. Significant varietal differences were reported at 95% confidence level using least significant difference (LSD) while differences in tuber maturity and storage were determined by standard errors of means

3. RESULTS

The results in Table 2 show that moisture content decreased from 73.43% at 5 months after planting (5MAP) to 70.18% at the 9th MAP. Similar increases in dry matter content during growth of yam, cassava and potato have been reported in the literature by different authors. Maximum dry matter accumulation has been reported at 9 months post emergence in 2 different cultivars of yam.⁹ Increases in dry matter content have also been reported in cassava and potato during growth to a maximum point followed by decreases.^{18, 19} There was a corresponding increase in dry matter content from 26.57 to 29.82. Slight reduction in moisture content (from 70.18 to 69.31%) of the tubers with corresponding increases in dry matter content was observed one month after the tubers were harvested and stored. Moisture continued to decrease gradually to the end of the storage period i.e. from 70.18% at harvest to 64.64% at 5MAH. Highly significant moisture loss (72.02-59.03%) during a 5 month storage period of *D. rotundata* tubers has been reported in the literature.²⁰

Table 2: Changes in mean physicochemical characteristics for 5 varieties of *D. alata* tubers at different harvesting periods

Months after Planting (MAP)	Fresh tuber		Flour					
	Moisture	Dry matter	Protein	Sugar	Starch	Amylose	Amylopectin	Swelling
5MAP	73.43a	26.57a	8.16a	4.04a	67.01a	23.59a	76.41a	10.12a
7MAP	70.45b	29.55b	6.64b	6.24b	73.49b	24.44b	75.56b	6.50b
9MAP	70.18b	29.82b	7.17c	3.80c	73.79c	29.78b	70.22c	6.13b
Mean	71.35	28.65	7.32	4.69	71.43	25.94	74.06	7.58
SEM	0.62	0.62	0.13	0.12	0.28	0.69	0.69	0.70

Changes in protein content did not follow any particular trend. It was observed in a similar study that storage did not cause any significant changes in crude protein of varieties studied.⁹ However, a significant and gradual reduction in crude protein contents has been reported in stored yam tubers of *D. rotundata* and *D. cayenensis*.²¹

Sugar content also did not follow any particular trend throughout the 3 different maturity stages (Table 2); however, it decreased slightly from 4.04% at 5MAP to 3.80% at 9MAP. The highest and significantly different sugar content was 6.24% at 7MAP. In storage, sugar content increased gradually from the 3.80% at harvest to 6.79% at 5MAH. Similar trend of increases in sugar content of stored tubers have been reported.^{22,23} After 120 days of yam tuber storage, Onayemi and Idowu²¹ reported that there was an increase in sugar content of tubers of *D. rotundata* and *D. cayenensis* with *D. rotundata* tubers showing higher increase.

Starch content increased significantly from 67.01% at 5MAP to 73.79% at 9MAP (Table 2). It however decreased significantly from the 73.79 at 9MAP to 65.35% at the end of the 5 month storage period (Table 3). Amylose content

increased significantly with increasing growth period, i.e. from 23.59% at 5MAP to 29.78 at 9MAP. It however decreased from the 29.78 to 25.16% at the end of the 5 months storage period. Similar results were obtained for other crops, such as maize, rice, and potato, whose amylose storage reserve increased with the age of the crops.^{25,26} Swelling power unlike amylose decreased with growth period, from 10.12% at 5MAP to 6.13% at 9MAP. However, it increased gradually to 8.67% at the end of the 5 months storage period.

Table 3: Changes in mean physicochemical characteristics for 5 varieties of *D. alata* tubers at different storage periods

Months after harvesting (MAH)	Fresh tuber		Flour					
	Moisture	Dry matter	Protein	Sugar	Starch	Amylose	Amylopectin	Swelling
1MAH	69.31a	30.69a	6.99a	4.36a	66.96a	26.25a	73.75a	6.16a
3MAH	70.79b	29.21b	7.05a	4.24a	77.48b	25.35b	74.65b	7.95ab
5MAH	64.64c	35.36c	7.48b	6.79b	65.35c	25.16b	74.84b	8.67b
Mean	68.25	31.75	7.17	5.94	69.93	25.59	74.41	7.59
SEM	0.97	0.97	0.35	0.39	0.69	0.20	0.20	2.04

Each value is a mean of the 5 varieties used (Table 1). Means followed by the same letter down the column are not significantly different ($p \leq 0.05$)

Table 4: Changes in mean pasting characteristics for 5 varieties of *D. alata* tubers at different harvesting periods

Months after Planting (MAP)	Peak	Trough	Breakdown	Final viscosity	Setback	Peak time	Pasting temp
5MAP	206.00a	192.76a	13.24a	249.80a	57.06a	6.66a	86.32a
7MAP	235.79b	210.26b	25.53b	264.58b	54.32b	6.18b	89.52b
9MAP	255.20c	229.92c	25.26b	297.64c	67.68c	5.98c	87.22c
Mean	255.20	210.98	21.34	270.67	59.69	6.27	87.69
SEM	18.77	6.86	1.73	5.88	2.09	0.12	0.70

Peak viscosity which is the maximum viscosity attained by the paste during the heating cycle (from 50 to 95 °C), increased from 206.00 RVU at 5MAP to 255.20 RVU at 9MAP (Table 4). Peak viscosity decreased during the first 3 month in storage and increased again at the end of storage (5MAH). Similar trend was observed for trough, breakdown, final and setback viscosities (Table 5). Similar increases in viscosities of stored *D. alata* tubers have been reported.²⁹ Changes in pasting temperature did not follow any particular trend during growth, however, there was a general decreased in value at the end of storage (87.22 at harvest to 84.10 at 5MAH) with corresponding decreases in peak time.

4. DISCUSSION

The increase in dry matter content of tubers from 5MAP to 9MAP is as a result of photosynthetic material accumulation in the tubers during growth. Steady increases in dry matter content of yam tubers from 3 months to 6 months after vine emergence have been reported in the literature³ Another study by Okoli⁴ indicated that dry matter accumulation in tubers of yam species peaked with subsequent reduction at complete senescence of the vines. The 9th month after planting which resulted in maximum dry matter and starch content presupposes that the tubers might have been harvested around the peak period where there is maximum accumulation of dry matter and starch as explained by Okoli.⁴ Traditionally, farmers use the dryness of vines as a sign of tuber maturity and, according to Abass,²⁰ higher tuber yields and better quality foods were obtained from tubers harvested when the vines were dried. Harvesting yam tubers 9 MAP or just as vines begin to dry up will be of more economic value for both farmers and processors because of the higher dry matter and starch contents as shown in this study.

Tuber moisture loss observed during storage is attributed to respiration and desiccation. Stored yam tubers continue to respire in the dormant state at reduced levels after harvesting. Consequently, they undergo some physiological and biochemical changes such as loss of tuber weight, sprouting, breakdown of starch to sugars, changes in protein and other tuber constituents. These are reported to affect food quality of stored tubers either positively or negatively.^{21, 11} *D. alata* is known as water yam partly due to the high moisture content of the tuber flesh. The tubers are traditionally stored to

lose moisture before consumption. It is believed that it taste better when dried or stored. Even though statistically significant, the observed moisture loss in this study is not drastic (70.18- 64.64%) as compared to 72.02-59.03% moisture loss in *D. rotundata* tubers within the same 5 months storage. The gradual moisture loss of *D. alata* tubers might be among the reasons why *D. alata* is said to keep well after harvesting.

The increase in starch content during growth of the tuber is due to transportation of photosynthetic materials translocated from the leaves to the roots as storage reserve in the form of starch. Yam exhibits a sigmoidal growth pattern with initial slow growth during establishment, followed by a phase of rapid exponential growth as the canopy reaches maximum area.⁵ The growth rate finally declines as the canopy senesces. Photosynthetic materials increase as the yam canopy (leaves) increases. However, during storage, stored starch is hydrolysed to sugars for physiological activities such as respiration hence the increases in sugar content with corresponding decreases in starch content (Table 3). It is known that sugar and starch exist in a state of dynamic equilibrium during storage.²⁴ There are reports in the literature of starch breakdown, mainly glucose and sucrose to maltose and fructose during storage of tubers of *D. alata* and *D. rotundata*.²³

The increases in amylose content with growth period could be explained by the increases in starch content observed in Table 2. Amylose and amylopectin are the main components of starch thus as starch content increases, amylose correspondingly increases. Again the slightly but significant decreases in amylose as a result of storage could be due to decreases in starch content of stored tubers. Lower swelling power at the 9th month of harvest and the subsequent increased during storage might have been influenced by the increase in amylose content respectively. Amylose is believed to restrict swelling by reinforcing the internal network of starch granules.^{27, 28}

The pasting behavior of flour/starch during cooking has been linked to its quality and suitability of use. Pasting properties are therefore an important quality index in predicting the behavior of yam flour/starch during and after cooking. The increases in pasting viscosities from 5 to 9MAP in this study could be attributed to the corresponding increases in dry matter and starch contents as the tuber matured (Table 2). The results in this study again support findings of other authors who obtained increased peak viscosity and breakdown values in late harvested potato than in early harvests.^{6, 7, 30} . The general decreased in pasting temperature at the end of storage (Table 5) with corresponding decrease in peak time means that less energy and time may be needed to cook stored *D. alata* tubers than freshly harvested tubers.

Table 5: Changes in mean pasting characteristics for 5 varieties of *D. alata* tubers at different harvesting periods

Months after Harvesting (MAH)	Peak	Trough	Breakdown	Final viscosity	Setback	Peak time	Pasting temp
1MAH	236.08a	201.80a	34.26a	255.44a	53.62a	5.32a	88.86a
3MAH	205.34b	187.04b	18.30b	239.10b	52.08a	6.26b	86.74a
5MAH	259.18c	220.88c	38.28a	304.80c	83.90b	5.84c	84.10b
Mean	233.53	203.24	30.28	266.45	63.20	5.81	86.57
SEM	13.27	13.51	8.28	11.38	9.08	0.20	2.53

The increases in dry matter and sugar contents, swelling power and pasting viscosities of stored tubers will have significant improvement in their organoleptic and textural properties. *D. alata* varieties with good eating quality are characterized by high dry matter, starch and amylose contents.³¹ While dry matter is an important chemical index of food quality in root and tuber crops, it has been reported to also influence the textural perception of foods.^{32,33} High setback and high pasting viscosities have been associated with cohesive paste³⁴ and a good pounded yam or *fufu*.^{35,36,37}

5. CONCLUSION

The results of this study has shown that both maturity or time of harvesting of *D. alata* (water yam) tubers and the length of storage have significant impact on the physicochemical and pasting characteristics of the species hence tuber food quality. Contents of moisture/dry matter, amylose, starch and sugar, swelling power and pasting viscosities seem to be more affected than other properties as a result of differences in the harvesting date and storage period. From this study, *D. alata* can be stored for up to 5 months without any major negative changes in the tuber. Pasting viscosities, dry matter and sugar contents increased with storage period. These may be among the reasons why *D. alata* is said to store well and even improve in food quality during storage. Farmers and processors may therefore harvest yam tubers at specific growth stages and store for specific periods depending on the intended use.

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