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Physicochemical and Pasting Characteristics of Water Yam (*D. alata*) in Comparison with Pona (*D. rotundata*) from Ghana

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Research Article

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ABSTRACT

The physicochemical and pasting characteristics of 18 varieties of *Dioscorea alata* (an underutilized yam species) were determined in comparison to *pona*, (a local and most preferred *Dioscorea rontundata* variety in Ghana) to contribute to knowledge base of *D. alata* for product diversification and further improvement. Tubers were randomly selected and moisture content determined before processing the remaining to flour for physicochemical and pasting characteristics. The results showed that test varieties had significantly ($p<0.05$) higher moisture and protein contents, higher peak time and pasting temperature but lower dry matter and starch content, lower swelling power and pasting viscosities in comparison with *pona.* Peak viscosity ranged from 74.80 to 284.60 RVU, trough (66.85 to 258.65 RVU), and breakdown (19.50 to 311.50 RVU). Peak time and pasting temperatures were 5.15 - 7.00 min and 83.60-90.10^{O}C respectively. *Pona* had 291.17 RVU as peak viscosity, 186.17 RVU troughs, 105.00 RVU breakdown and 422.75 RVU final viscosity. Others were: setback (236.58 RVU), peak time (4.73 min) and pasting temperatures (79.88 ^{o}C). The physicochemical properties in conjunction with the pasting properties of the test varieties suggest the presence of strong bonding forces within their starch granules. Pastes from test varieties were relatively more stable when cooked hence will have a lower tendency to undergo retrogradation during freeze/thaw cycles than the reference variety. The study has shown significant variations among *D. alata* varieties and between the *D. alata* and *pona*. This could lead to selection and improvement of *D. alata* varieties for specific food applications to stimulate their production and utilization.

Keywords: Yam, D. alata; water yam; pona; physicochemical; pasting characteristics.

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1. INTRODUCTION

Yam (*Dioscorea* spp.) is an elite crop, preferred over other root and tuber crops in West Africa, the leading producer of yams. Yam is estimated to feed millions of people and is extremely important for at least 60 million people comprising rural producers, processors and consumers in West Africa (Babaleye, 2005). Apart from serving as food, yam has a lot of potential industrial uses but unfortunately has not been commercially processed to any significant extent.

Dioscorea alata is one of the six yam species of economic importance but in Ghana, it is less utilized for major food products as a result of traditional bias which fails to recognize the unique quality characteristics and the good agronomic flexibility of the species. The species has high yield, high multiplication ratio and better tuber storability, than the preferred indigenous *D. rotundata. D. alata* has an advantage for sustainable cultivation especially when yam production seems to be on the decline as a result of high cost of production, low yields and post harvest losses among others.

The quality of products from root and tuber crops such as yam is known to be primarily determined by the physicochemical and pasting characteristics. For this reason, many authors including Rasper and Coursey (1967); Moorthy (2001); Afoakwa and Sefa-Dedeh (2002); Sahorè *et al.* (2005) and Riley *et al.* (2006), have studied and reported on the physicochemical and pasting characteristics of yam. However, *D. alata* has not been studied extensively especially in Ghana as compared to the other root and tuber crops (Hoover, 2001) probably because of its perceived unimpressive food quality traits. The texture of its flesh is usually not as firm as that of *D. rotundata* (white yam) and less suitable than other species for the preparation of the most popular food products from yam (*fufu,* pounded yam and boiled yam) in the West Africa region. Physicochemical properties such as moisture/dry matter, sugar and starch, amylose and swelling power and pasting properties are important in determining product performance, and have influence on sensory characteristics of the food products in which yams are incorporated. These properties are therefore important for characterization and industrial application purposes.

The aim of this study was to study the physicochemical and pasting characteristics of 18 *D. alata* varieties in comparison with a reference variety, *pona* (the preferred variety of *D. rotundata* in Ghana) to bring out the differences between two species and to contribute to knowledge base of the species for product diversification and improvement. To achieve these, tubers of selected varieties were processed to flour and analysed for physicochemical properties such as moisture/dry matter, protein, sugar and starch, amylose and swelling power by standard methods while pasting characteristics were determined by Rapid Visco-Analyser.

2. MATERIALS AND METHODS

2.1 Source of Materials

Eighteen (18) varieties of *D. alata* were collected from CSIR-Crops Research Institute, Kumasi for the studies. *D. rotundata* variety, locally known as *pona* was bought from Kumasi Central market and used as a reference. The test varieties were planted in Fumesua near Kumasi and harvested after 9 months.

2.2 Experimental Procedure

2.2.1 Sampling

Six tubers from each variety were selected from a bulk of harvested tubers by simple randomization procedure. Tubers were washed and peeled and each was divided into four longitudinal portions after the tips of the proximal ends were cut off. The 1^{st} two opposite portions from each tuber was selected and pooled together, diced into small pieces (cubes), thoroughly mixed and converted to flour for physicochemical and pasting characteristics. Each laboratory determination was duplicated.

2.2.2 Preparation of yam flour

Peeled yam tubers were diced into cubes and dried in an air convection oven at 60 ^{o}C for 72 hours. The resulting dried chips were milled into fine flour (250 μm mesh size) and stored in whirl-pac sample bags at -20 °C for analysis.

2.2.3 Laboratory analysis

2.2.3.1 Determination of moisture/dry matter content

The moisture/dry matter content of yam tubers were determined using standard AOAC (1997) method.

2.2.3.2 Determination of protein

Crude protein content was done using HACH (1990) method. 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.

2.2.3.3 Determination of total sugar and starch contents

The starch and total sugar contents were determined using a colorimetric method by Dubois *et al.* (1956). Hot ethanol was used to extract sugar from the yam flour sample. Sample residue was digested with perchloric acid to its monosaccharides for starch estimation. The extract (supernatant) and digest (from residue) were quantified calorimetrically for sugar and total starch respectively, using phenol-sulphuric acid as colour developing reagent and absorbance read at 490 nm using a spectrophotometer (model Spectronic 601, Milton Roy Company, USA).

2.2.3.4 Determination of amylose content

The colorimetric method of Juliano (1971) and Williams *et al*. (1958) which involves the preparation of stock iodine solution was used. Absorbance was read using spectrophotometer at 620 nm. A blank was used to standardize the spectrophotometer.

2.2.3.5 Determination of swelling power

The method described by Leach *et al*. (1959) was used. Swelling power was calculated as follows:

$$\text{Swelling power} = \frac{\text{Weight of sediment}}{\text{Sample weight} - \text{Weight of soluble}}$$

2.2.3.6 Determination of pasting characteristics

Pasting characteristics were determined with a Rapid Visco Analyser (RVA Super 3, Newport Scientific pty. Ltd, Australia) by Newport Scientific (1998). Three grams (3g) of flour (at 14% moisture level) was mixed in 25 ml of water in a sample canister using the formula below. The sample was thoroughly mixed and fitted into the RVA as recommended by Newport Scientific (1998). With the use of the 12-min profile, the slurry was heated from 50 ^{o}C to 95 ^{o}C with a holding time of 2 min. This was followed by cooling to 50 ^{o}C with another 2 min holding time. Both the heating and cooling was at a constant rate of 11.25 ^{o}C / min with constant shear at 160 rpm. Corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak time, and pasting temperature from the pasting profile were read on a computer connected to the RVA.

Formula used:

$$S = \frac{86 \times A}{100 - M}$$

$W = 25 + (A - S)$

Where S= corrected sample mass

A=sample weight at 14% moisture basis (depending on the type of sample, this is taken from the general guide on weight of sample from RVA manual)

M=actual moisture of the sample (% as is)

W=corrected water mass

2.2.4 Statistical analysis

The data obtained from the studies were analysed using Statistical Analysis Systems (SAS) package (version of SAS Institute Inc, 2003). Analysis of variance and means separations were done by the general linear model procedure with a probability of $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Characteristics

Moisture content of the *D. alata* varieties ranged between 56.47 for TDa 98/01174 and 79.31% for TDa 297 with a mean of 69.07% (Table 1). Statistical analysis showed significant differences ($p < 0.05$) among the test varieties and then between the test varieties and *pona* (56.99%). Moisture contents between 66.20% and 77.70% have been reported for *D. alata* varieties grown in Nigeria (Baah *et al*., 2009). The moisture contents of the yam tubers in this study were high as expected; because root and tuber crops such as yams are characterized by high moisture content. The high moisture content is a disadvantage because it predisposes fresh tubers to high postharvest losses.

Table 1: Physicochemical characteristics (mean %) of *Dioscorea alata* and *D. rotundata* (*pona*)

	Fresh tuber		Flour				
Species/variety	**Moisture**	**Dry matter**	**Protein**	**Sugar**	**Starch**	**Amylose**	**Swelling Power**
D. alata							
Apu	69.27	30.73	9.05	3.56	71.34	25.58	7.29
TDa 291	70.16	29.85	5.87	2.86	64.01	28.19	6.78
TDa 297	79.31	20.7	7.88	6.91	63.76	23.63	8.87
TDa 98/01168	74.3	25.7	7.72	4.09	69.74	24.11	7.07
TDa 98/01174	69.93	30.07	6.04	3.31	70.52	25.54	7.39
TDa 98/01176	56.47	43.53	5.07	3.18	77.56	21.69	7.36
TDa 99/00022	67.72	32.28	7.57	4.83	71.42	24.66	8.3
TDa 99/00048	65.45	34.55	7.21	4.62	70.7	25.78	8.27
TDa 98/00049	72.89	27.12	6.19	4.36	60.42	26.65	7.96
TDa 99/00199	66.86	33.14	5.94	4.28	61.01	27.84	7.88
TDa 99/00214	69.18	30.83	5.95	4.38	62.28	26.49	9.75
TDa 99/00395	69.07	30.94	6.18	5.31	65.58	23.33	6.23
TDa 99/00446	66.84	33.16	6.71	2.43	62.81	24.23	6.27
TDa 99/00528	71.44	28.56	6.51	5.52	63.68	27.79	6.47
TDa 99/01169	64.27	35.73	5.77	5	68.55	28.17	8.22
KM 1999	71.08	28.93	7.1	5.47	74.51	31.56	7.39
WM 2001	69.68	30.33	5.26	2.44	67.83	31.14	7.55
WM 2003	69.43	30.57	5.16	4.47	63.83	28.95	7.88
Min	56.47	20.7	5.07	2.43	60.42	21.69	6.23
Max	79.31	43.53	9.05	6.91	77.56	31.56	9.75
Mean	69.07	30.93	6.51	4.28	67.2	26.41	7.6
SE	1.09	1.09	0.25	0.28	1.15	0.63	0.21
LSD	4.81	4.81	0.3	4.13	0.22	1.25	1.24
D. rotundata							
Pona	56.99	43.01	3.46	4.6	70.26	27.36	12.05

Dry matter content ranged from 20.70% to 43.53% for the test varieties and 43.01% for the reference variety. Dry matter content of test varieties was relatively lower than the reference variety with the exception of TDa 98/01176. Similar values for dry matter (13.68 - 37.4%) have been reported in the literature for *D. alata* by Baah *et al*. (2009) and Lebot *et al.* (2005). Dry matter is an important food quality parameter in root and tuber crops and relates positively with good eating qualities and good textural properties (Lebot et al., 2005).

Protein content of the test varieties (*D. alata*) ranged between 5.07% for TDa 98/01176 and 9.05% for *Apu*. There were highly significant (P<0.05) varietal differences in protein content of the test varieties. The variations may be due to genetic composition of the varieties and environmental conditions (Woolfe, 1987). Similar ranges of protein content (4.30 – 11.95%) were obtained for *D. alata* in earlier studies (Baah *et al.,* 2009 and Lebot *et al.,* 2005). *Pona*, the *D. rotundata* reference variety, had comparatively lower protein content (3.46%) which supports literature values for *D. rotundata* in comparison with *D. alata* (Baah *et al*. 2009; Osagie, 1992). Yam is an important root and tuber crop in terms of nutritional composition; it has higher protein and vitamin C content and virtually no cyanogenic compounds as compared to cassava (FAO, 1999). Sugar content ranged from 2.43% (TDa 99/00446) to 6.91% (TDa 297) while the reference variety had a value of 4.60%. Starch content ranged from 60.42% to 77.56% compared to 70.50% obtained for *pona*, the reference variety. Tuber crops such as yam are quite rich in starch, accounting for 60 to 89% carbohydrates (Muthukumarasamy and Panneerselvam, 2000). In a similar study, Baah *et al*., 2009 reported 5.40% for sugar and 78.3% for starch in *D. alata* from Nigeria. *Pona* is one of the most preferred white yam cultivars in Ghana because of its good taste and good cooked texture characteristics which make it have superior qualities for *ampesi* or boiled yam (a common and important yam product in Ghana). Sugar and starch contents influence the suitability of yam for different products (Baah *et al.*, 2009). While sugar confers characteristic sweetness to yam, starch impacts textural qualities to the tuber. Starch is also a dominant factor in determining the physicochemical, rheological and textural characteristics of yam products.

The *D. alata* varieties had amylose content ranging from 21.69% to 31.56%, the reference variety; *pona* had a value of 27.36%. No significant difference (P<0.05) was observed between the average test variety and *pona*, however, highly significant differences existed among the test varieties. Amylose content of yam starch is reported to be between 14-30% depending on the species, with 21-30% amylose for *D. alata*, 21-25 % for *D. rotundata* and 21-25% for *D. cayenensis* (Moorthy, 2002). Amylose is a major component of starch which influences pasting and retrogradation behaviours (Zhenghong *et al*., 2003) and impart definite characteristics to starch (Moorthy, 1994). Viscosity parameters during pasting are cooperatively controlled partly by the properties of the swollen granules and the leached out soluble materials (mainly amylose) from the granules (Singh *et al.,* 2006).

Swelling power of the varieties ranged from 6.23 to 9.75%. *Pona*, the reference variety had significantly (p<0.05) higher value of 12.06%. *D. roundata* is known to have higher swelling power in comparison to other species of yam (Baah *et al.,* 2009; Walter *et al.*, 2000) as observed in this study. Swelling power is largely controlled by the strength and character of the micellar network within starch granules. Thus, the lower swelling power values obtained for the test varieties could be as a result of highly ordered internal arrangement in their starch granules.

Table 2: Pasting characteristics of *D. alata* varieties and *D. rotundata* (*pona*)

Serial no.	Species/Variety	Peak Visc. † (RVU)	Trough (RVU)	B. Down‡ (RVU)	Final Visc. (RVU)	Setback (RVU)	Peak time (Min)	Pasting temp. (^oC)
	D. alata							
1	Apu	78.2	71.1	85.5	116.5	45.4	7.0	87.2
2	TDa 291	190.1	175.1	179.5	210.7	35.6	5.3	83.6
3	TDa 297	146.7	143.3	41.0	178.8	35.6	7.0	87.2
4	TDa 98/01168	74.8	66.9	95.0	112.3	45.4	7.0	90.1
5	TDa 98/01174	177.4	174.0	40.5	210.0	36.0	7.0	86.9
6	TDa 98/01176	165.9	163.9	23.0	222.4	58.5	6.7	84.1
7	TDa 99/00022	89.9	88.3	19.5	115.8	27.5	5.7	85.3
8	TDa 99/00048	201.3	196.9	52.5	249.2	52.3	5.8	85.3
9	TDa 98/00049	170.7	165.2	66.5	213.3	48.2	5.5	84.4
10	TDa 99/00199	284.6	258.7	311.5	317.2	58.6	6.4	88.2
11	TDa 99/00214	148.3	129.1	230.0	163.7	34.7	5.2	86.1
12	TDa 99/00395	93.2	88.6	55.0	131.3	42.7	7.0	85.5
13	TDa 99/00446	117.6	113.9	44.5	152.5	38.6	7.0	84.0
14	TDa 99/00528	167.9	160.3	92.0	208.5	48.2	7.0	87.4
15	TDa 99/01169	217.2	212.0	63.0	261.1	49.2	7.0	83.7
16	KM 1999	147.2	131.7	186.5	194.3	62.6	7.0	88.9
17	WM 2001	217.2	212.0	63.0	261.1	308.1	7.0	83.7
18	WM 2003	150.0	147.9	25.5	193.2	45.4	6.8	84.8
	Min	74.80	66.85	19.50	112.25	27.45	5.15	83.60
	Max	284.60	258.65	311.50	317.20	308.10	7.00	90.10
	Mean	157.66	149.91	93.00	195.08	59.56	6.49	85.89
	SE	12.88	12.30	19.05	13.38	14.79	0.16	0.46
	LSD	18.12	17.25	24.85	23.04	180.01	0.15	1.36
	D. rotundata							
	Pona	291.17	186.17	105.00	422.75	236.58	4.73	79.88

† visc. = viscosity; ‡ B. Down=breakdown

3.2 Pasting Characteristics

Peak viscosity of the varieties ranged from 74.80 to 284.60 RVU for TDa 98/01168 and TDa 99/00199 respectively. Values for trough were from 66.85 to 258.65 RVU while breakdown was from 19.50 to 311.50 RVU. Final viscosity of the varieties ranged from 112.25 to 317.20 RVU with setback viscosity ranging from 27.45 to 308.10 RVU. Peak time and pasting viscosity were 5.15 - 7.00 min and 83.60-90.10 ^{O}C respectively. *Pona* on the other hand had 291.17 RVU as peak viscosity, 186.17 RVU troughs, 105.00 RVU breakdown and 422.75 RVU final viscosity. Others were: setback (236.58 RVU), peak time (4.73 min) and pasting temperatures (79.88 ^{o}C). Pasting viscosities of the test varieties were on the average lower than *pona*, the reference variety, however, peak time and pasting temperatures were significantly ($P<0.05$) higher in the test varieties as compared to *pona* (Table 2). Highly significant differences ($P<0.05$) existed among the *D. alata* varieties.

Peak viscosity reflects the ability of starch granules to swell freely before their physical breakdown. The lower peak viscosities of test varieties may be as a result of the relatively lower swelling power obtained (Table 1). Low swelling power, low starch content and high dietary fibre contents were reported to have influenced peak viscosity in *D. alata* varieties (Baah *et al*., 2009). Peak viscosity relates with product quality hence significant differences observed among the test varieties studied may influence their performance in product development.

The most commonly used parameter to determine starch-based samples quality is final viscosity, it indicates starch/flour ability to form a gel after cooking. Final viscosity is the viscosity after cooling cooked paste to 50 ^{o}C. The significantly higher values obtained for final viscosities as compared with the peak viscosities (Table 2) is due to high degree of association between starch-water systems and their high ability to re-crystallize, resulting in progressively higher viscosities during cooling of yam starches (Ayernor, 1985).

Yam starch has a high setback as a result of retrogradation in comparison with other root and tuber crops (Mali *et al*., 2003; Peroni *et al*., 2006). The test varieties had significantly lower setback values than *pona*, the reference *D. rotundata* variety (Table 2). Generally the tendency of yam starch paste to retrograde is a limiting factor for its use in food industries. The lower setback observed for *D. alata* flour samples in this study suggest that its flour/starch is relatively more stable when cooked and will have a lower tendency to undergo retrogradation during freeze/thaw cycles than the reference sample. High setback in *D. rotundata* has also been observed by other authors (Baah *et al.*, 2009; Otegbayo, 2006). Setback correlates positively with cohesive paste (Kim *et al*., 1995) and good pounded yam or *fufu* (Oduro *et al.*, 2000; Otegbayo *et al.*, 2006). The lower setback values obtained for *D. alata* varieties may therefore be among the reasons why the species is not preferred for pounded yam in yam growing areas.

The relatively higher peak time and pasting temperature observed in the test varieties means that relatively longer time and higher minimum temperatures may be required to cook *D. alata* as compared to *pona* (*D. rotundata*). Similar results were obtained for peak time and pasting temperature by different authors (Baah *et al*., 2009; Otegbayo *et al.,* 2006).

4. CONCLUSION

D. alata varieties had significantly higher moisture and protein contents with higher peak time and pasting temperature as compared with *pona,* the reference variety. However, dry matter and starch content, swelling power and pasting viscosities were comparatively lower in test varieties to *pona*, the reference. The physicochemical properties in conjunction with the pasting properties of the test varieties suggest the presence of strong bonding forces within their starch granules. Pastes from test varieties were also relatively more stable when cooked and will have a lower tendency to undergo retrogradation during freeze/thaw cycles than the reference variety. The study has shown significant variations among *D. alata* (test) varieties and between the test varieties and *pona*. The results obtained in this study add to the knowledge base of *D. alata* and could help in their use in specific food applications to stimulate their production and utilization.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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REFERENCES

Adebowale, A.A., Sanni, L.O., Awonorin, S.O. (2005). Effects of texture modifiers on the physicochemical and sensory properties of dried fufu. Food Sci. Tech. Intl., 11(5), 373-382.

Baah, F.D., Maziya-Dixon, B., Asiedu, R., Oduro, I., Ellis, W.O. (2009). Physicochemical and pasting characterisation of water yam (*Dioscorea* spp.) and relationship with eating quality of pounded yam. Journal of Food, Agriculture and Environment, 7(2),107-112.

Afoakwa, E.O., Sefa-Dedeh, S. (2002). Viscoelastic properties and changes in pasting characteristics of trifoliate yam (*Dioscorea dumetorum*) starch after harvesting. Food Chemistry, 77, 203-208.

AOAC. (1997). Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edition. The Association: Arlington, VA.

Ayernor, G.S. (1985). The Yam (Dioscorea) Starches. In: Advances in Yam research. 1st ed. Godson Osuji. Anambra State University of Technology Publishers. Nigeria., pp.79-88.

Dubois, M.,Gilles, K.A.,Hamilton, J.K., Rebers, P.A., Smith, F. (1956). Colorimetric method for determination of sugars and related substances. Anal. Chem., 28, 350-356.

FAO. (1990). Food and Agriculture Organisation. Action Programme for the Prevention of Food Losses, Improving Post-harvest Handling, Storage and Processing of Root and Tuber Crops, Rome, Italy.

HACH. (1990). Procedures Manual. Systems for Food, Feed and Beverage Analysis. Colorado: Hach.

Hoover, R. (2001). Composition, molecular structure and physicochemical properties of tuber and root starches. Carbohydrate Polymers, 45, 253-267.

Juliano, B.O. (1971). A simplified assay for milled rice amylose. Cereal Science Today, 16, 334-340.

Lebot, V., Malapa, R., Molisale, T., Marchand, J.L. (2005). Physico-chemical characterization of yam (*Dioscorea alata* L.) tubers from Vanuatu. Genetic resources and Crop Evolution, 00, 1-10.

Leach, H.W., McCoven, L.D., Scoch, T.J. (1959). Structure of the Starch granule. Swelling and solubility patterns of various starches. Cereal Chem., 36, 534-544.

Mali, S., Ferrero, C., Redigonda, V., Beleia, A.P., Grossmann, M.V.E., Zaritzky, N.E. (2003). Influence of pH and hydrocolloids addition on yam (*Dioscoria alata*) starch pastes stability. Lebensmittel-Wissenschaft und Technologies, 36, 475-481.

Moorthy, S.N. (2001). Tuber crop starches, Thiruvananthapuram: Central Tuber Crop Research Institute, Thiruvananthapuram, Kerala, India., pp. 4-52.

Moorthy, S.N. (1994). Tuber crop starches. Technical bulletin series 18. Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Muthukumarasamy, M., Panneerselvam, R. (2000). Carbohydrate metabolism in yam tubers during storage and sprouting, Trop Science., 40, 63-66.

Newport Scientific. (1998). Applications manual for the Rapid visco^{TM} analyzer Using thermocline for windows. Newport Scientific Pty Ltd., 1/2 Apollo Street, Warriewood NSW 2102, Australia., pp. 2-26.

Oduro, I., Ellis, W.O., Aryeetey, S.K., Ahenkora, K., Otoo, J.A. (2000). Pasting characteristics of starch from new varieties of sweetpotato. Tropical Sci., 40, 25-28.

Osagie, A. U. (1992). The Yam in Storage. Postharvest Research Unit, University of Benin, Nigeria.

Otegbayo, B., Aina, J., Asiedu, R.,Bokanga, M. (2006). Pasting characteristics of fresh yams (*Dioscorea* spp.) as indicators of textural quality in a major food product.-'pounded yam'. Food Chemistry, 99, 663-669.

Peroni, F.H.G., Rocha, T. S., Franco, C.M.L. (2006). Some structural and physicochemical characteristics of tuber and root starches. Food Sci. Tech Int., 12(6), 505-513.

Rasper, V., Coursey, D. G. (1967). Properties of starches of some West African yams. J. Sci. Food Agric., 18, 240-244.

Riley, C.K., Wheatley, A.O., Asemota, H.N. (2006). Isolation and characetrisation of starches from eight *Dioscorea alata* cultivars grown in Jamaica. African Journal of Biotechnology, 5(17), 1528-1536.

Sahorè, D.A., Amani, N.G., Nemlin, G.J. (2005). The properties of starches from some Ivory Coast wild yam (Dioscorea) species. Tropical Science, 45(3), 122-125.

SAS Institute Inc. (2003). SAS® 9.1 Qualification Tools User's Guide SAS Institute Inc, Cary, NC, U. S. A.

Walter, W.M., Truong, V.D., Wiesenborn, D.P., Carvajal, P. (2000). Rheological and Physico-chemical Properties of starches from Moist and Dry-type Sweet potatoes. J. Agric. Food Chem. 48, 2937-2942.

Williams, V.R., Wu, W., Tsai, H.Y., Bates. (1958). Varietal differences in amylose content of rice starch. Journal of Agricultural and Food Chemistry, 6, 47-48.

Woolfe, J.A. (1987). The potato in the human diet. Cambridge Univ. Press. Cambridge, UK.